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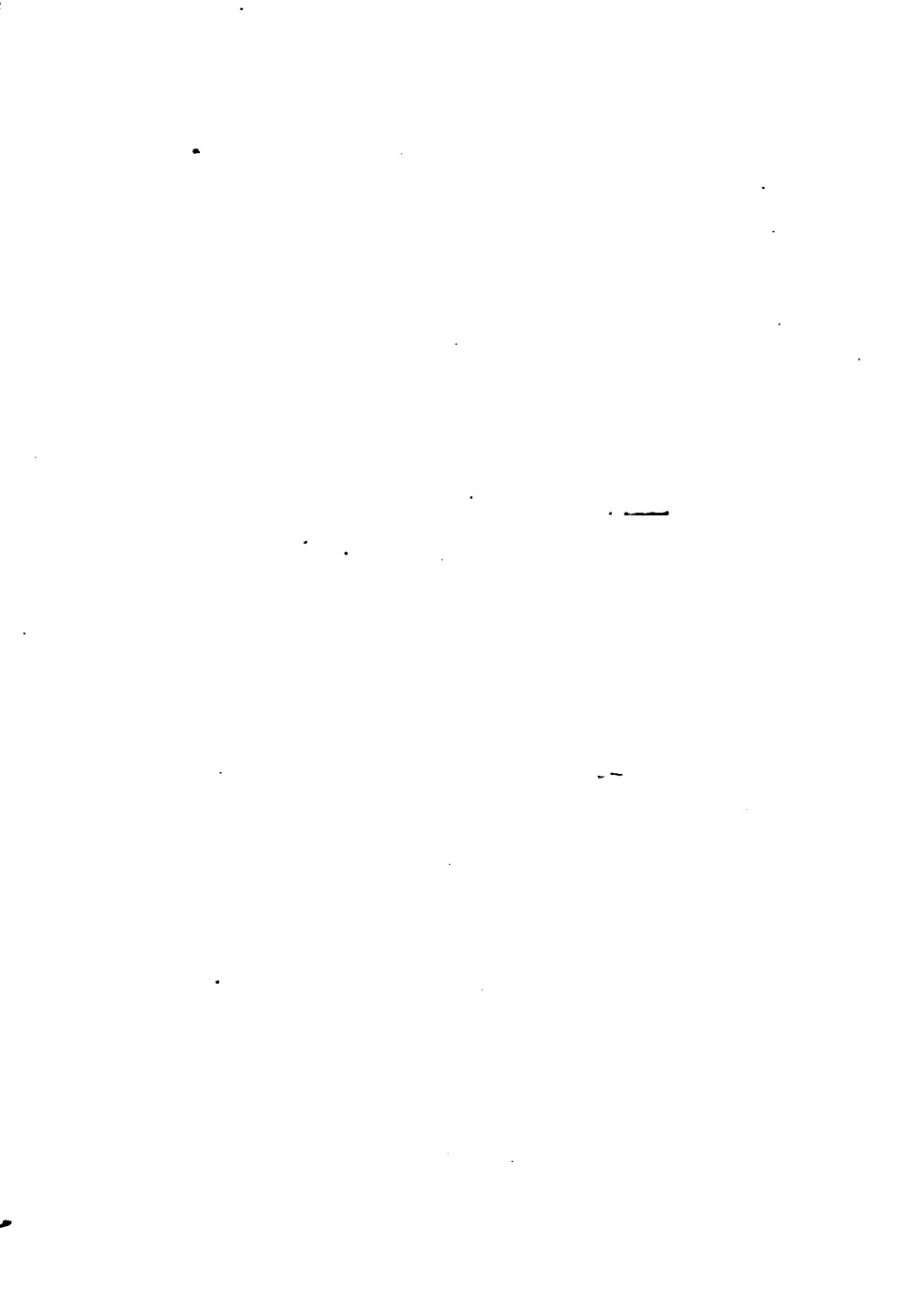
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STATIONARY ENGINEERING

BY

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A REFERENCE AND TEXT BOOK

WRITTEN EXPRESSLY FOR

Stationary Engineers and Firemen

ALSO

Mechanical Engineers

Consulting Engineers

Electrical Engineers

Universities and Schools

WITH 300 ILLUSTRATIONS

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PREFACE

THE purpose of this book is to present in a compact form those principles which underlie a thorough knowledge of power and heating plants, together with such data on the subject of mechanical and electrical engineering as is deemed essential in the successful operation of power and heating plants of every description.

It has been the object of the author to deal with the subjects herein treated, in a *practical* way as applied to every day work, rather than with theories and mathematical problems.

The name, nature and function of the principal parts of every machine or apparatus have therefore been given before any directions for its operation or use.

Believing that it is impossible for the general reader to fully understand any mechanical device from a mere description of same without the use of a model or an illustration accompanying the description, an unusually large number of full page sectional views of all the devices as described has been included, together with complete specifications for the construction and installation of same, so the reader may fully inform himself upon the construction of any machine or apparatus that he may be called upon not only to operate, but also at times to repair.

Owing to the varied requirements of modern power plants, and the high boiler pressures necessary for the operation of modern expansion engines and turbines, the *respon-*

sibility of the stationary engineer has been vastly increased in the last few years.

When we further consider that many plants now generate their own power for the operation of their lights, motors and elevators, and also do their own refrigeration, it can be seen that the modern stationary engineer must not only be a steam engineer, but an electrical and refrigerating engineer as well.

In fact, the day is not far distant when stationary engineering as a *profession* will be considered as one of the most important branches of engineering, and the *stationary engineer* worthy of the highest reward for his services and well known devotion to his duty.

JOSEPH G. BRANCH.

St. Louis, November, 1906.

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STATIONARY ENGINEERING

CHAPTER I.

THE STEAM BOILER.

The Steam Boiler.—The steam boiler in its original form consisted simply of a closed spherical vessel partly filled with water, which was heated by a furnace, or by a fire box placed underneath it. This vessel, or boiler as it was called, contained the water to be evaporated into steam, and the furnace, or fire box, contained the fuel to be burned.

From this simple device, first used in a practical way by Newcomen in about 1709, have grown the modern boilers and furnaces, which have made possible the great steam plants of the present day, that are necessary to meet our modern requirements.

A boiler then is simply a vessel constructed for the purpose of generating steam to be used either for power or heating purposes.

Essential Parts.—From their first conception to the present time, all boilers have had the following parts: The vessel, or shell, which contains the water to be evaporated into steam; the furnace, or fire box, in which the fuel is burned, and a chimney to carry away the smoke and gases of combustion, and produce at the same time the necessary draft for burning the fuel. With the boiler and furnace, are various appliances and attachments necessary for the safety and economy of their operation.

Use.—Boilers are used either for **power** or for **heating** purposes, depending upon the character of the work to be performed by them.

Those used for **power** are designated as high-pressure boilers, and furnish steam for the operation of engines and turbines; while those furnishing steam for **heating** purposes in connection with the ordinary heating systems, are designated as low-pressure boilers, they usually being allowed to carry not more than fifteen pounds of steam to the square inch.

Owing to the higher pressure carried on power boilers, they necessarily are constructed much stronger, and differ also in many essential details.

The early types of boilers were constructed exclusively for power purposes, usually for the operation of pumps; the use of boilers for heating purposes being of much more recent date.

DEVELOPMENT OF THE STEAM BOILER.

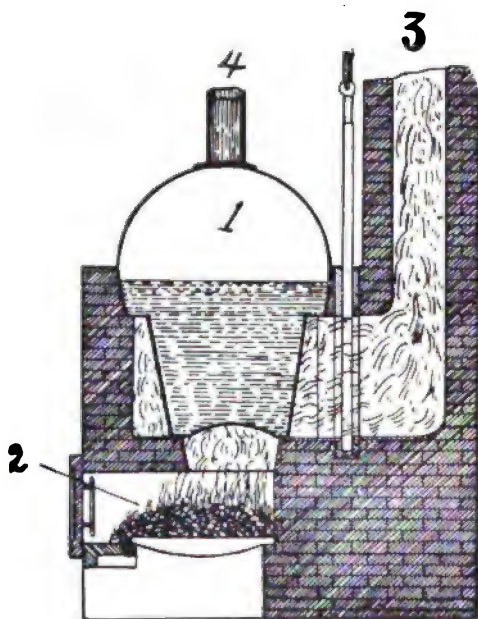
In order to thoroughly understand the construction and operation of boilers, one must study their development from their first conception and practical use to the present time. In this way their defects and the improvements made upon them can be more readily understood.

The Newcomen "Spherical" Boiler.—One of the earliest forms was a spherical boiler designed by Newcomen in about 1709. It was constructed of cast iron, and the brick setting supporting the boiler was so arranged that the hot gases from the furnace, which was placed directly under the sphere, passed through a flue which surrounded the boiler just below the water line

and led up to the chimney opposite the furnace. It is evident that this boiler could be of but little practical use, but it was the first step in the development of the steam boiler which rapidly followed.

The Newcomen "Balloon" Boiler.—A few years later Newcomen designed the first practical boiler. It was a vertical cylindrical boiler, called from its shape, the "Balloon" or "Haystack" boiler. This boiler was made of wrought iron with a hemispherical top and arched bottom, as shown in Fig. 1. The steam space necessary in every boiler, is designated by the numeral 1, the furnace underneath the shell by 2, the flue conveying the hot gases around this shell and up the chimney by 3, and the steam outlet from the boiler to the engine, by 4. From this, it can be seen that this boiler possesses the first essentials of all steam boilers, viz.: a vessel to contain the water; a furnace underneath it and a flue to bring the hot gases of combustion in contact with this vessel; sufficient space above the water in the vessel to hold the steam; and lastly, a chimney to convey away these gases and supply the necessary air for combustion.

Defects.—The principal defect in this boiler was the lack of sufficient **heating surface** exposed to the fire and hot gases. By the heating surface of a boiler we mean only that portion of the shell which is brought into actual contact with the fire and heated gases, and it is evident the greater the heating surface, the greater amount of heat can be imparted to the water, and consequently the greater the amount of evaporation of same into steam. A steam boiler is used to make steam required for the work to be performed. This is the chief consideration, and all boilers are constructed with this object in view. The boiler that can evaporate the most water into



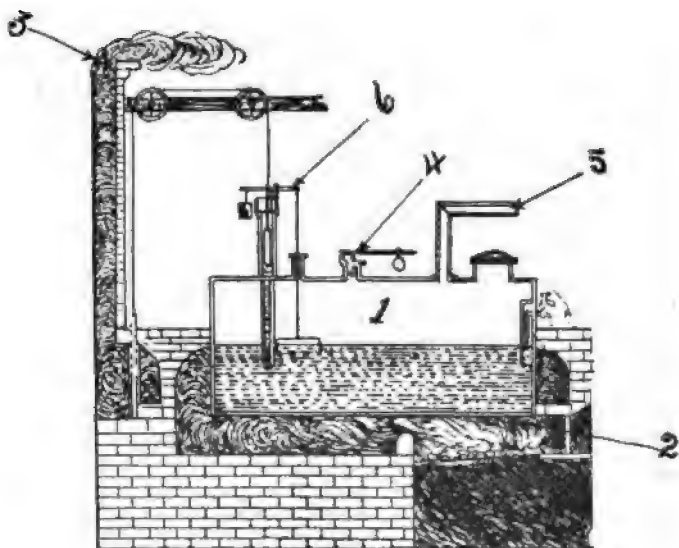
The Haystack or Balloon Boiler, Designed by Newcomen.
Fig. 1.

steam with the greatest economy, is the most successful boiler, and for over two hundred years it has been the constant endeavor of engineers the world over to produce a perfect boiler, i. e., a boiler in which there will be no loss of heat, but its entire utilization in the work to be performed.

The Watt "Wagon" Boiler.—In order to improve upon the boiler above described, Watt designed a horizontal boiler having a greater heating surface. From its resemblance to a wagon top, this boiler was called the "Wagon" boiler, Fig. 2. The top was hemispherical, and the bottom curved inward. The products of combustion passed from the grate underneath the boiler to the rear, then through the left-hand flue to the front, and from there it passed through the right-hand flue, passing the front of the boiler to do so, finally escaping up the chimney. From the circuit taken by the heated gases first under and then around the shell, this was called the wheel draft.

In the larger sizes, the heating surface was further increased by placing a flue in the boiler through which the gases returned to the front of the boiler after passing to the rear, as in the smaller sizes. The gases, on issuing from the flue at the front, divided and passed to the chimney at the rear of the boiler by flues placed in the brick work on either side.

The travel of the gases was much longer in this boiler than in the "Balloon" boiler, which was a great improvement, as the greater the travel of the gases, the greater is the amount of heat conveyed to the water to be evaporated. Should the heated gases have too short a travel between the furnace and the chimney, they will be permitted to escape up the chimney while retaining



The Wagon Boiler, Designed by James Watt.
Fig. 2.

much of their heat. Such loss of heat means a waste of fuel, and no boiler can be a successful boiler which is so constructed as to permit this waste. In any properly constructed boiler and furnace, the heat of the furnace is about 2,000 degrees Fahrenheit, while the heated gases rarely escape under ordinary conditions above 600 degrees Fahrenheit. This means that there has been 1,400 degrees of heat given up during the travel of the gases. With a properly constructed boiler and under proper conditions the temperature of the chimney gases can be reduced as low as 400 degrees Fahrenheit, but this is rarely done under ordinary conditions. To reduce the temperature of the gases below this point would affect the draft.

Attachments.—Watt used with this boiler a water column in the feed pipe which served as a pressure gauge. The rise and fall of this column not only designated the amount of steam pressure in the boiler, but also controlled the damper which regulated the draft. The feed water was regulated by a float, which, while not now in use, gave to engineers their present idea of automatic boiler feed regulators.

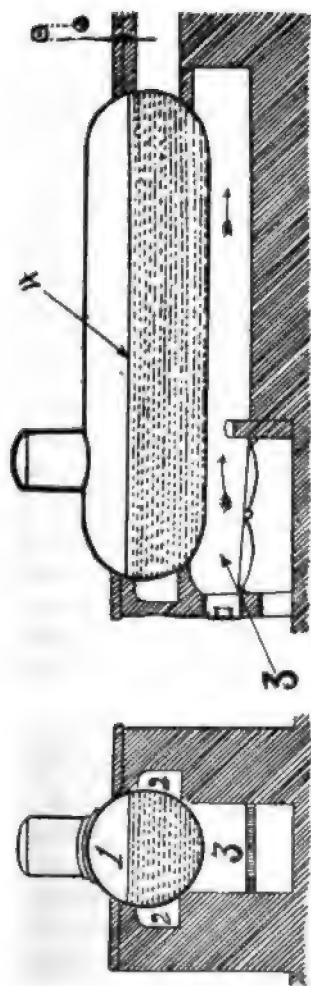
Defects.—The chief defect in this "Wagon" boiler was its **weakness**, owing to its shape and the absence of all stays and braces. For low-pressure purposes, not exceeding 15 pounds per square inch, it was a practical and useful boiler, but for high-pressure work it was entirely unsuitable.

In Fig. 2, showing this boiler, the numeral 1 is the shell, 2 the furnace, 3 the chimney, 4 the safety valve, 5 the steam outlet to the engine and 6 the automatic pressure gauge and damper regulator.

"Cylindrical" Boiler.—Watt's "Wagon" boiler was succeeded about the beginning of the present century by the first of the **modern** type of boilers. This was the plain "Cylindrical" boiler made of wrought iron, with flat or hemispherical ends, known as the "Egg end" boiler. The egg shape of the ends of this boiler greatly increased its strength over that of the "Wagon" boiler, the principal defect of which was its **weakness**.

Defects.—Owing to the shape of this boiler no staying is required, its form, with the exception of the sphere, being the strongest to resist rupture. The heating surface is small, unless the boiler is made very long, which is a decided disadvantage. All the sediment collects in the bottom of the shell where the heat is the greatest, which soon causes the plates to burn, and also prevents, together with the scale which soon forms, the proper conduct of the heat to the water. These boilers are necessarily small of diameter, being from 30 to 42 inches, and quite long, being from 20 to 50 feet, and are extremely wasteful of fuel. They can therefore for this reason be only used in places where fuel is abundant, as in mining districts, and around blast furnaces.

This boiler is shown in Fig. 3. The numeral 1 is the shell, the ends being set horizontally in brick work. The lower part of this cylinder contains the water, the upper part the steam, 2 the flues on each side of the shell, 3 the furnace outside the cylinder, which consists simply of grate bars set in the brick work at a convenient distance below the bottom of the shell. The fuel is thrown on the bars through the fire door which is set in the front brick work. The air necessary for combustion enters between the grate bars from below through the ash pit. The flame and hot gases pass over the bridge wall



The Cylinder Boiler.
Fig. 3.

close under the boiler, thence along the flue to the rear, returning to the front through the flue on one side of the shell and back again on the other side to the far end of the boiler, whence they escape up the chimney. Numeral 4 is the water line of boiler.

This boiler is a great improvement upon the earlier types of boilers, but has the two great defects above named, viz.: the lack of proper heating surface, and the deposit of solid matter of the water on the highly heated portion of the shell forming the bottom of the boiler.

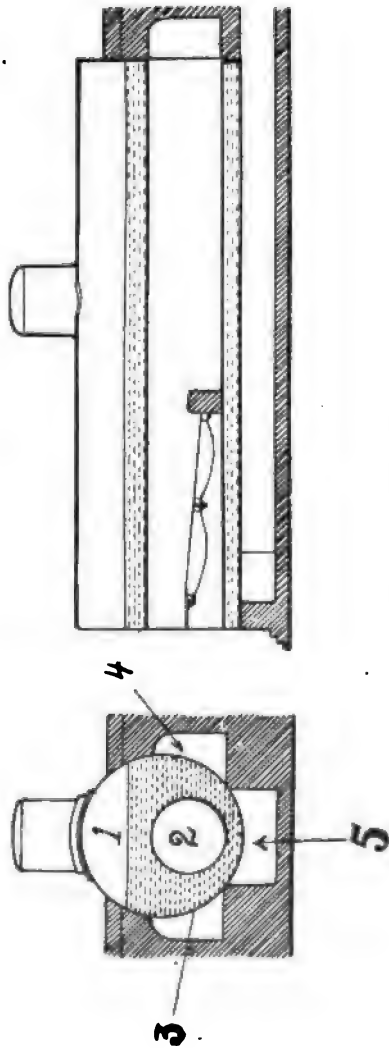
In addition to these two defects, also, owing to the difference in temperature of the gases due to their long travel, the expansion and contraction of the metal composing the shell of the boiler is very unequal, producing cracks in the metal and rupture of the joints. While the travel of the gases in the earlier types of boilers was much too short, in this boiler it is **too great**, owing to the three turns under and around the boiler, which they are forced to take before escaping up the chimney.

As these boilers are frequently made 40 feet long, the gases would be required to travel 120 feet before reaching the far end of the boiler. As their temperature on starting at the forward end of the boiler would be about 2,000 degrees Fahrenheit, after traveling 120 feet in contact with the cooling surface of the boiler, they would be at times reduced to a temperature barely sufficient to produce a draft in the chimney. The effect of this was to highly heat one end of the boiler, leaving the other end cold.

This boiler possesses many of the requirements of the modern boiler, and it should therefore be thoroughly understood before beginning the study of the more modern types.

The "Cornish" Boiler.—Upon the defects of the above boiler becoming apparent, a Cornish engineer named Trevithick, in order to increase the heating surface of same, conceived the idea of placing the fire **inside** an **internal flue** which ran the entire length of the shell. This type of boiler is known as the "Cornish boiler," Fig. 4. It consists of a cylindrical shell with flat ends as shown in the cut. The furnace, however, instead of being outside of the shell, is **enclosed** in a second cylinder or flue having a diameter a little greater than half of that of the boiler shell. This gave an additional heating surface of the entire length and diameter of this second cylinder or flue. The arrangement of the grate and bridge wall is evident from the cut. After passing over the bridge wall, the gases travel through this internal cylinder or flue until they reach the rear end of the boiler, returning to the front again through the two side flues, and thence back again to the chimney through a bottom flue. The numeral 1 in the cut is the outer cylinder or shell, 2 the internal cylinder or flue, 3 and 4 the side flues, and 5 the bottom flue through which the gases pass finally to the chimney.

Advantages.—This type of boiler removed one of the chief objections to the "Cylinder" boiler, by reducing the temperature of the heated gases before they came in contact with the bottom of the boiler where the sediment collects. It further increased the amount of the heating surface of the boiler by an amount equal to the surface of the internal flue, but as the diameter of this internal flue had to be made sufficiently large to contain the furnace, it practically prevented the making of this boiler in small sizes. It was the first type of what is known as the **internally fired boiler**.

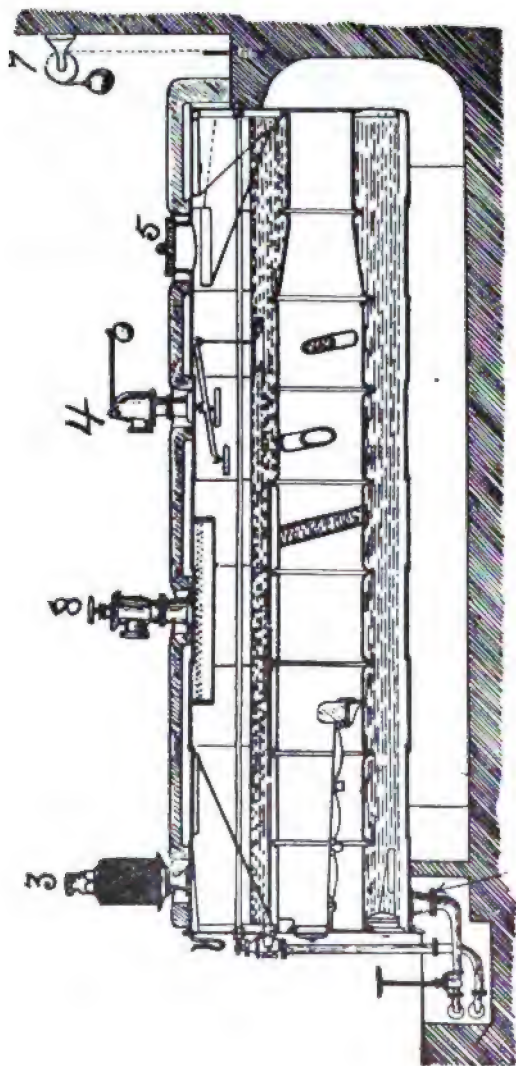


The Cornish Boiler.
Fig. 4.

Defects.—The chief defect of this boiler is the unequal expansion and contraction due to the use of the outer and inner cylinder; as the internal flue is the hottest portion of the boiler, and consequently undergoes much greater expansion than the other cylinder. The result is to bulge out the ends of the boiler, and then when the boiler cools down, or is out of use, the flue contracts to its regular size, and thus has a tendency to work loose from the ends to which it is riveted. Should the ends be too rigid to move, a serious strain is thrown on both the ends of the flue and the heads of the boiler. Even while in use the flue of this boiler undergoes great changes in temperature, according to the state of the fire. This constant expansion and contraction so weakens the flue that it frequently collapses, resulting in great disaster and loss.

“Lancashire” Boiler.—To rectify these most serious defects, the next step in the development of the steam boiler was the production of the Lancashire boiler, shown in Figs. 5 and 6.

In this boiler it will be observed there are two internal furnaces instead of one, as in the “Cornish” boiler. These furnaces usually emerge into one internal flue, though sometimes each flue continues to the other end of the boiler as a separate flue. These furnaces are supposed to be fired alternately, and the smoke and unburned gases from the fresh fuel in one flue are aided in their combustion by the hot air proceeding from the other furnace. In this way all violent changes in the temperature are avoided, as well as the waste of fuel due to unburned gases. In the cuts showing this boiler, the numeral 1 is one of the internal furnaces, and 2 indicates what are known as the Galloway tubes.



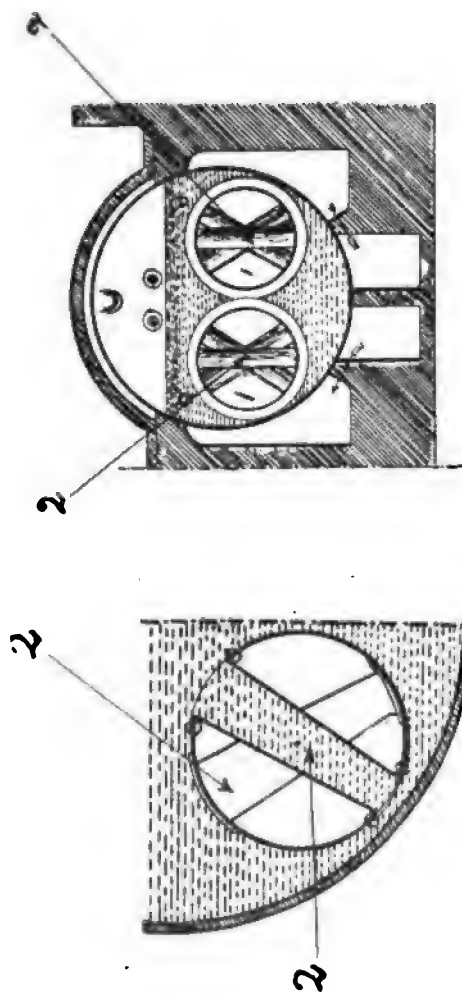
The Lancashire Boiler.
Fig. 5.

"Galloway" Tubes.—These tubes are connected across the flues as shown in Fig. 6, and not only contribute to strengthen the flues, but they add greatly to the heating surface, and greatly promote the circulation of the water to be evaporated.

These Galloway tubes were the first step towards the development of what is known as the **water tube** boiler.

In order to fully realize what an important step these tubes form in the development of the steam boiler, it is sufficient to say that there can be no steam evaporated from water in any useful quantities, where there is no **circulation** of the water itself. It is the rising of the heated particles of the water to the top, and the descent of the cooler ones to the bottom upon which the formation of steam depends. It is therefore absolutely necessary that there be some circulation of the water in all boilers, and the efficiency of the boiler depends to a great extent upon the proper circulation being afforded. The greater the circulation, the more rapid the evaporation, and, to a large extent the greater the efficiency of the boiler. The Lancashire boiler was the first boiler in which an attempt was made to secure a proper circulation, and while the method pursued was most primitive, it marked a great advance in stationary engineering.

The Lancashire boiler fitted with these Galloway tubes is shown in Fig. 5, together with the numerous boiler attachments, which added both to its safety and economy. The cut represents a longitudinal section of the boiler together with these fittings. There are two **safety valves** shown on top of the boiler, one being 3, which is of the dead-weight type and which will be de-



Section of Galloway Tubes and Furnace.
Fig. 6.

scribed hereafter; and 4, being a low-water safety valve. This last valve is operated by means of a lever and rod which are attached to a float, which rests on the surface of the water. Upon the water sinking below its proper level, the float also sinks, causing the valve to open, thus allowing steam to escape and giving an alarm. 5 is the manhole with its cover plate, which manhole admits of access to the interior of the boiler. 6 is the mud hole through which the sediment accumulating along the bottom of the boiler, is raked. 7 is the damper and 8 the steam outlet. On the front of the boiler are attached the pressure gauges, the water gauges, and the furnace door, as well as the feed pipe and the blow-off pipe. There are also two iron doors by which access may be gained to the two lower external flues for cleaning purposes.

Advantages.—The Galloway, or Lancashire boiler, as it is variously called, is considered a most economical boiler, both in this country and in England. A great many exhaustive tests and experiments have been made with this boiler, and its great worth is universally recognized.

Defects.—The disadvantage of this boiler is the difficulty of securing adequate space for the two furnaces without unduly increasing the diameter of the shell. Where the furnaces are too small, there cannot be complete combustion owing to the cold crown plate of the boiler coming in contact with the heated furnace; while the narrow space between the fuel and the crown sheet does not permit of the proper quantity of air being supplied above the fuel necessary for perfect combustion.

MODERN TYPES OF BOILERS.

Modern Boilers.—The development of the modern types of boilers from the Lancashire, or Galloway boiler, was but a short step.

It was soon found that the placing of an internal flue in the shell not only greatly increased the heating surface, but added to the strength of the boiler, so additional flues were added; and as the number of the flues were increased it became necessary to **decrease** their diameter, until finally the present types of horizontal tubular boilers were produced.

Upon decreasing the diameter of the flues, they soon became too small to be used for furnace purposes, and the furnace was then placed on the **outside** of the shell, making the boiler an **externally** fired boiler.

From the placing of the furnace either **inside** or **outside** of the shell, all steam boilers are divided into two principal classes, viz.: (1) Internally fired boilers, and (2) Externally fired boilers.

Classes of Boilers.—All steam boilers are further divided into two classes according to the **course** taken by the gases after leaving the furnace; one class being composed of (1) **shell or fire tube boilers**, in which the hot gases pass **through** the flues or tubes, thus heating the water which surrounds them; while the second class are composed of (2) **water tube boilers**, in which the gases pass **around** the flues or tubes, and in this way heat the water which **fills** the tubes.

Multitubular Boiler.—The continual increase of the number of flues, or tubes as they are called when less than 6 inches in diameter, developed what is known as

the multitubular or return tubular boiler, in which there are as many as 130 3-inch tubes, or 84 4-inch tubes.

While the number and diameter of these tubes vary, the following number and sizes are generally used in boilers of this type, under ordinary conditions.

Number of Tubes Usually Put in Return Tubular Boilers.

HAND-HOLE UNDER TUBES.					MAN-HOLE UNDER TUBES.			
Diam. Boiler.	2½-in. Tubes.	3-in. Tubes.	3¼-in. Tubes.	4-in. Tubes.	Diam.	3-in. Tubes.	3¼-in. Tubes	4-in. Tub s.
36	38	26	..	..	..	..	..	..
42	52	38	..	..	42	..	22	18
44	..	38	34	22	44	28	26	20
48	..	52	38	34	48	44	28	26
54	..	54	44	34	54	56	44	36
60	..	82	64	54	60	62	54	44
66	..	..	72	54	66	88	66	54
72	..	..	92	72	72	124	86	70
..	..	..	..	..	78	132	100	84

This type of boiler is illustrated in Figs. 7 and 8, the last being a longitudinal cross-section of same.

It is the most popular form of boiler in general use, possessing many advantages over all other types, the first of which is its **cheapness**.

Advantages.—Its principal advantages are its steady steaming qualities, its durability and adaptability to any class of work.

Its Principal Disadvantages.—(1) Its lack of safety;

(2) Its slow steaming qualities, owing to the large body of water to be heated;



The Horizontal Flue Boiler.
Fig. 7.

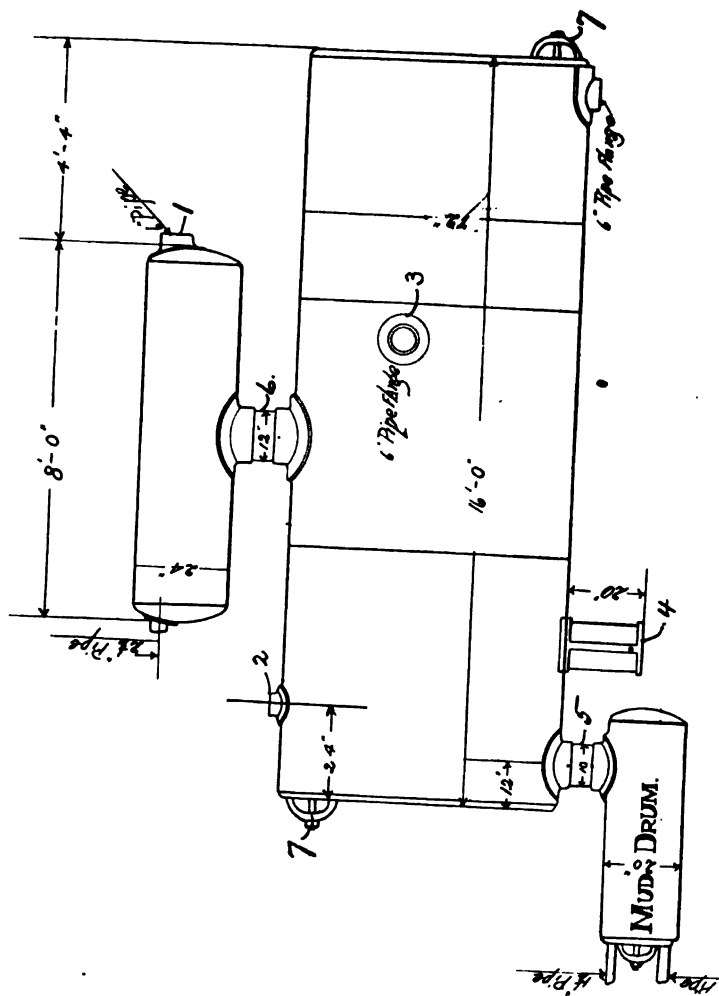
(3) The liability of the tubes or flues to rupture, owing to the large diameter necessary for same;

(4) The amount of space necessary for boiler setting.

Furnace.—It is usually an externally fired boiler, the furnace being entirely **outside** of the shell of the boiler.

Construction.—The boiler itself consists of a wrought iron or steel cylindrical shell, which is filled with the tubes or flues terminating in the two flat ends, into which they are expanded. About one-third the volume of the boiler is occupied by the steam, the other two-thirds being the water space in which are the tubes or flues. In order to prevent the **burning** of these tubes, the water line, that is the line at which the water should be carried in the boiler, is about two inches **above** the top row of all the tubes or flues. The portion of the heads of the boiler below the water line are stayed by the tubes, while that above the water line is stayed either by through stay rods, or by diagonal stays. The boiler is usually supported by brackets riveted to the shell. The front brackets are usually fixed in the side walls on either side, but the rear brackets should be so arranged that they move upon rollers, so that the shell cannot be strained by the expansion and contraction of the plates.

The feed pipe may enter either at the front or rear of the boiler, but it should always terminate in a perforated pipe **below** the water line. The blow-off pipe is at the rear of the boiler, this being the lowest point of the shell, as a boiler is usually set with a slight inclination toward the rear so that the sediment will collect near the blow-off pipe. This pipe is also often used to blow out sediment, and to empty the boiler.



Longitudinal Section of a Horizontal Tubular Boiler
Showing Steam and Mud Drum.
Fig. 8.

Heating Surface.—In this type of boiler, the heating surface is composed of about **one-half** of the shell, together with the inside of all the tubes or flues, and about **two-thirds** of the two ends or tube sheets, as these surfaces come in contact with the fire and heated gases. It is therefore seen that all the heating surface is **below** the water line.

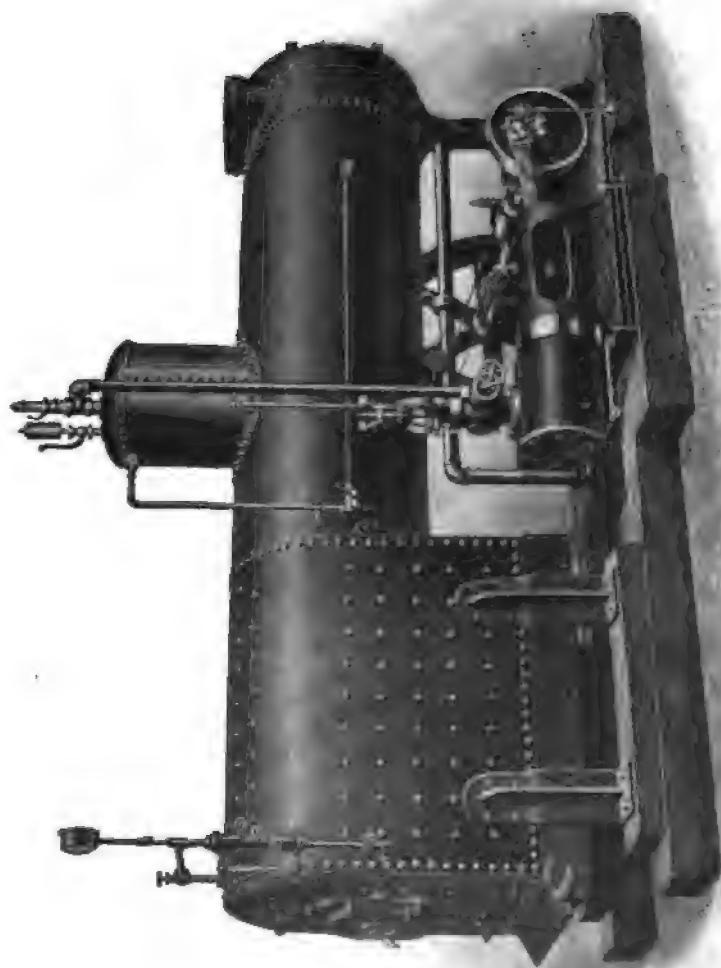
Fig. 13 is a cross-sectional view of a flue and of a multitubular boiler, in which 1 is a cross-section of a **flue boiler**, and 2 that of a **tubular boiler**.

Locomotive Boiler.—Next to the multitubular boiler, the locomotive boiler is used in this country more than any other type. It is used exclusively on railroads, and is also largely used as a stationary boiler.

Construction.—The general construction of this boiler is shown in Figs. 9 and 10. The front part of the shell is cylindrical, while the rear part which contains the furnace, is of a rectangular shape. A space is left between the sides of the shell and the end of the furnace, which space is filled with water and is known as the "water leg" of the boiler. A number of tubes extends from the front sheet of the furnace, or fire box as it is called in this type of boiler, to the front head of the shell. The boiler is supported at the front end by a cast-iron cradle which rests upon a foundation usually made of masonry. The rear end is supported upon a brick wall, which also forms the ash pit.

The gases of combustion pass directly from the furnace through the tubes to the smoke box and thence out of the stack.

Forced Draft.—In locomotives on railroads a forced draft is produced by causing the exhaust steam from



The Locomotive Type of Boiler.
Fig. 9.

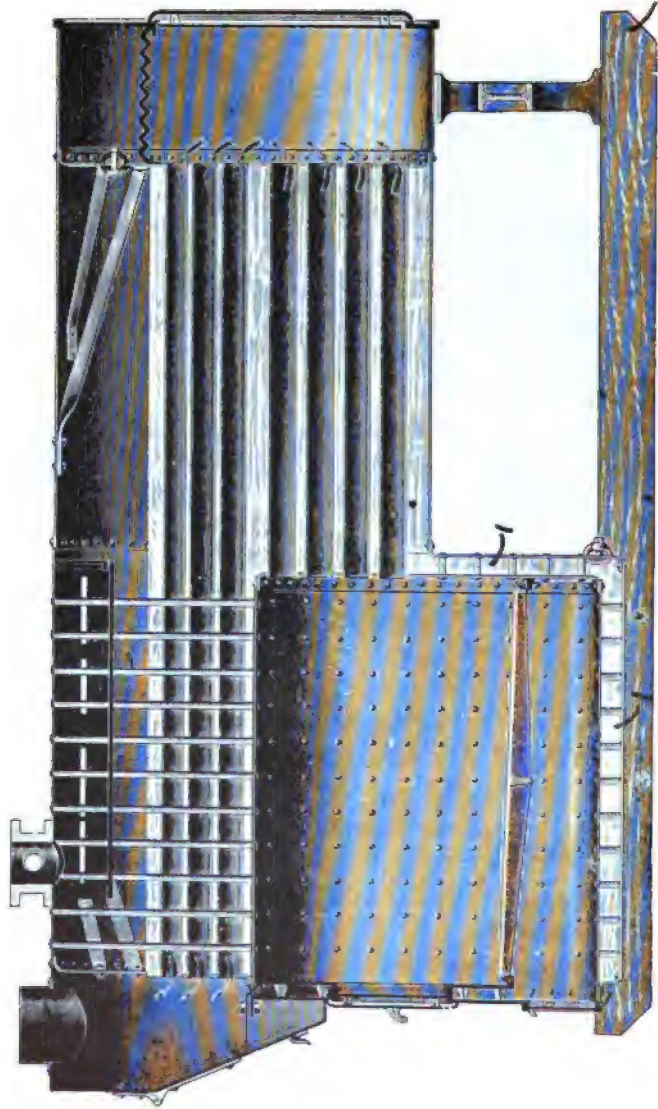
the cylinders to be discharged into the chimney by means of a pipe called the blast pipe. At each discharge of exhaust steam escaping up the chimney it forces the air out in front of it, causing a partial vacuum, which can only be supplied by the air rushing through the furnace and the tubes, thus causing the draft.

Advantages.—The chief advantages of this boiler are its economy and its ease of installation.

Disadvantages.—Its disadvantages are, the trouble of keeping clean and inspecting it, and the difficulty of repairing same.

The Vertical Boiler.—This type is simply a modification of the locomotive boiler placed on end. A common form of the vertical fire tube boiler is shown in Figs. 11 and 12. This boiler consists of a cylindrical shell having an internal circular fire box or furnace. The ends of the tubes are expanded into the upper head of the cylindrical shell, and at the bottom into the top, or crown sheet of the furnace. The grates are supported by rings riveted to the internal wall of the fire box. The top of the boiler is made dome shape, in the center of which is placed the chimney, which is formed of the usual wrought iron plates. The furnace, which is placed at the bottom of this shell, is entirely surrounded by water, except the bottom in which is placed the grate. The connection of the tubes determines whether the boiler is (1) A through tube boiler as shown in Fig. 11, or "Dry top," as it is sometimes called; or, (2) A submerged-tube boiler, as shown in Fig. 12. The latter type is preferable, but more expensive.

Use.—These boilers are used where floor space is valuable, and there is sufficient height. While in general



Section of a Locomotive Boiler.
Fig. 10.

they are not as economical as other types of boilers, they are becoming more universally used owing to their many other good qualities.

Principal Advantages.—(1) Entirely self contained.

(2) The small amount of floor space required.

(3) Ease of installation.

(4) Portable character, permitting them to be removed from one place to another with ease and dispatch.

(5) Their extreme simplicity.

(6) Their low cost, and durability.

Principal Disadvantages.—(1) Their lack of safety.

(2) Waste of fuel owing to short travel of the gases, and lack of proper circulation.

Water Tube Boilers.—Figs. 13, 14, 15 and 16 illustrate common types of water tube boilers. In such a boiler the water circulates through a series of tubes of comparatively small diameter, which communicate with each other and with a common steam chamber. The flames and hot gases are made to circulate between them, and are usually forced by baffle plates or walls, to be made to act equally on all parts of the tubes before being allowed to escape up the chimney.

While there are many varieties of this type of boiler, the above description constitutes the essential principles of them all.

In the best forms of these boilers, they are suspended entirely independent of the brick work from wrought iron girders, resting on iron columns.

Advantages.—(1) Safety from explosions, owing to the contents of the boiler being divided up into small portions throughout the water tubes, water legs and steam drums. Should there be a rupture in the tubes, or any part of the boiler, only the immediate contents will



Sectional View of a Vertical Fire Tube Boiler.
Fig. 11.

be liberated, instead of the entire mass of water and steam.

(2) The tubes being of much smaller diameter than would be necessary if they were only a few in number, they can be made much smaller and hence stronger, and therefore less likely to rupture.

(3) Owing to their contents being held in small portions, instead of in a large mass of water, they possess quick steaming qualities.

Disadvantages.—(1) They require more masonry for their setting, and occupy more space than shell boilers.

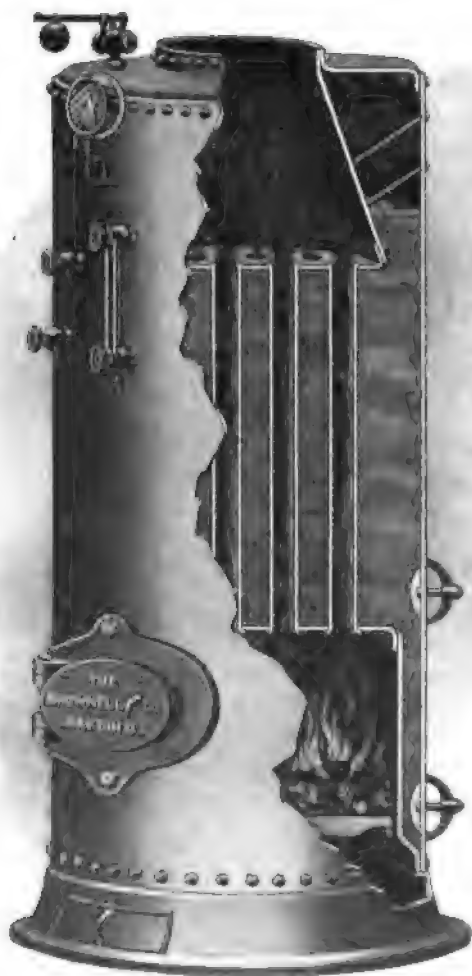
(2) Owing to the water being held in small quantities, irregular firing is apt to cause a violent generation of steam, producing sudden fluctuations of pressure, which may result in priming and thereby overheating the tubes.

(3) While this type of boiler is very susceptible for cleaning, the scale which forms in the tubes at times becomes very difficult to remove.

The Internal Furnace Boiler.—The types of boilers heretofore described have all been Internal Furnace Boilers, with the exception of the Horizontal Return Tubular and Water Tube Boilers, but none of them are designated by the character of their furnace alone.

Figs. 17, 18 and 19 illustrate on the contrary what is known as the Internal Furnace Boiler, the character of the furnace being its most prominent feature.

Advantages.—The chief advantage of this type of boiler for ordinary work, is the economy of first cost, they being "self contained," that is, they are independent of any masonry setting, cast-iron fronts, buckstays, tie rods, etc., therefore they require but little founda-



A Vertical Fire Tube Boiler With Submerged Tubes.
Fig. 12.

tion, and are susceptible of being easily removed from one location to another.

They are also capable of carrying an extremely high steam pressure and are at the same time steady steamers.

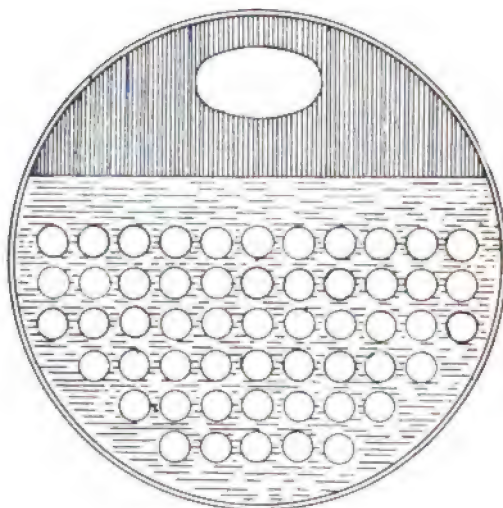
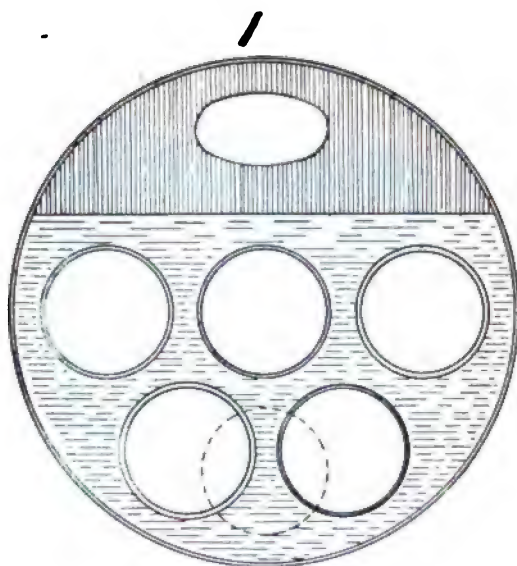
Owing to the furnaces being entirely surrounded by water, the heat of combustion is utilized to a greater extent than is practical with external furnace boilers. These boilers are extremely economical in the consumption of coal, not only for the above reasons, but owing to the absence of all brick setting, which settings usually crack and allow the heat to escape.

Disadvantages.—The principal disadvantages of this type of boiler is the short travel of the gases, thereby permitting them to escape at too high a temperature up the stack.

The circulation is also defective owing to faulty construction, and the improper distribution of the heating surface.

Dry Back.—This boiler is a modification of what is known as the Clyde or Scotch Marine Boiler and is often called a **Dry Back Scotch Boiler** from the fact that the combustion chamber is not surrounded by water.

The Marine Boiler.—This boiler as illustrated in Fig. 20, consists of a large cylindrical shell (1), the ends of which are closed by flat heads (2), a large flue (3) of the corrugated type, known technically as the **Morrison Suspension Furnace Flue**, extends the entire length of the boiler and is securely riveted to the two heads, which are flanged inward. Above and around this large flue and below the water line is a nest of tubes (4) which extend from head to head. The front ends of these tubes open into a smoke box (5) that connects with the chim-



2
 Cross Sections of Horizontal Flue and Tubular Boilers.
 Fig. 13.

ney or stack (6). The flat heads are stayed by the through rods (7) which are in the steam space, and which prevent the deflection of the heads.

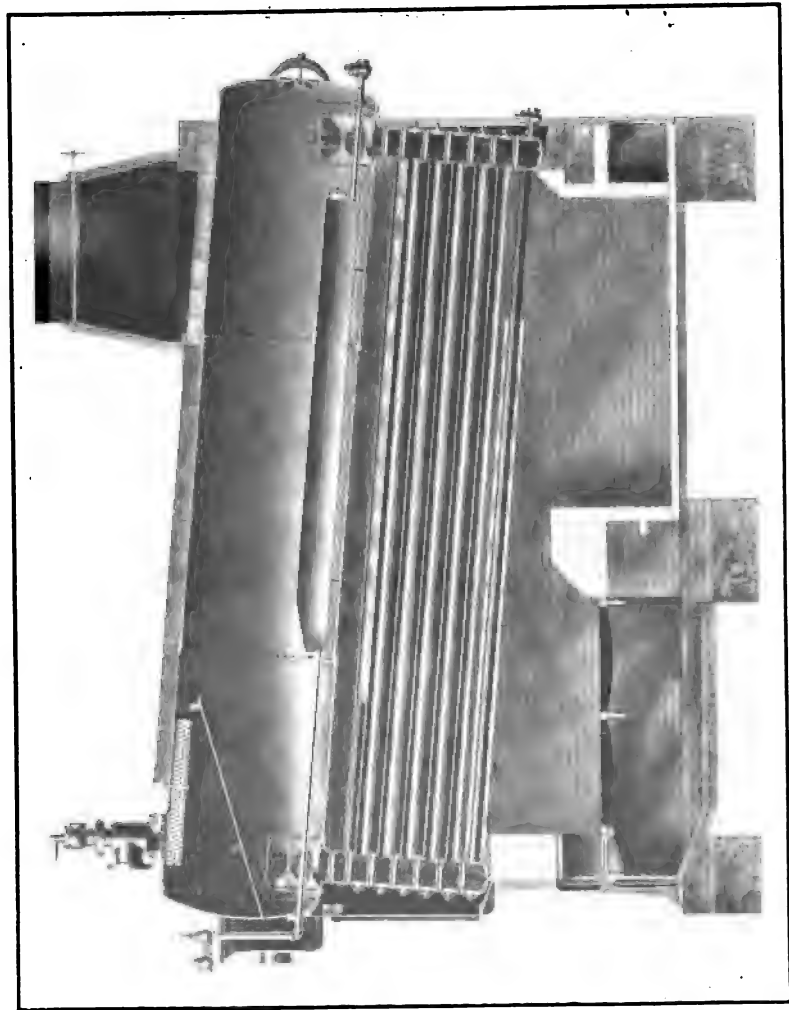
The remaining parts of the flat heads are supported by the tubes, which are first expanded and then beaded over, and also by the furnace flue. The furnace (8) is placed within the furnace flue and consists of the usual grate (9), ash pit (10) and bridge (11). The gases of combustion flow to the rear into the combustion chamber (12), and then pass through the tubes to the front and into the smoke box. The sides of the combustion chamber are stayed to each other and to the shell plate of the boiler, forming a water chamber or back between the combustion chamber and the shell of the furnace (13), making it a "Water back" boiler, which is the essential difference between it and the "Dry back" boiler used exclusively for stationary work.

Marine boilers over 9 feet in diameter usually have two furnaces, those over 14 feet, three furnaces, while the largest boilers used on first-class mail steamers, often exceeding 15 feet in diameter, have four furnaces.

Summary.—All boilers can therefore be divided into three classes, viz.: Stationary, Locomotive and Marine; and these into six types, viz.: Flue, Tubular, Water Tube, Locomotive, Vertical, and Marine.

BOILER MATERIAL.

Destructive Forces.—From the time the steam boiler is constructed until it is finally destroyed there are numerous agents continually at work which tend to weaken it. These forces, or agents, attack the boiler both from the outside and from the inside, and in consequence the



Sectional View of a Water Tube Boiler.

life of all boilers is limited. Their attack is most insidious, and unless carefully watched will finally destroy the strength of the boiler even before it is suspected that they are at work. On the other hand there is nothing from which the boiler can draw sustenance to replace its losses. The atmosphere without and the water within the boiler, are both most destructive agents. The water itself which is evaporated within the boiler contains injurious minerals, which attack the metal from the time that the water is fed into the boiler until it is evaporated into steam. In addition to these injurious ingredients, there are also organic substances in the water, which likewise attack the metal. The fuels which are burned in the furnace, contain even more injurious forces which attack it from the outside of the shell. Among the most injurious of these forces found in fuel are the sulphurous and other acids contained in the fuel. These forces are not only at work when the boiler is in use, but also when it is not in use. It can therefore be seen how necessary it is that great care be taken of a boiler, and why it is that only competent engineers and firemen should be placed in charge of them.

This would not be so necessary if the only loss in the deterioration or destruction of a boiler was a financial loss, but when we consider the enormous force pent up in them, liable at any time to spread death and destruction around them should they be weakened beyond a point of safety, or, should an incompetent person be placed in charge, we then can understand why it is that the steam boiler is surrounded at all times with every precaution, and the public safety protected by the most rigid laws.

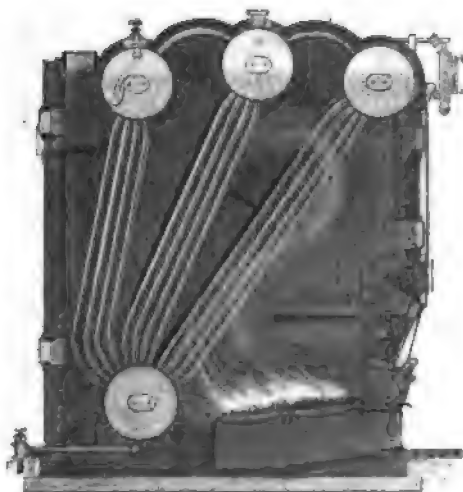
The material selected for the construction of boilers must not only be of great strength, but also must be elastic and durable.

Cast Iron was the material of which the earliest forms of boilers were made, but it has been entirely discarded in the construction of the modern high pressure boilers, and now only used in low pressure boilers for heating purposes where the steam pressure carried rarely exceeds 15 pounds to the square inch.

This is due to its low tensile strength and its unreliable nature. It possesses the advantage of cheapness and qualities to resist corrosion, and while it has been found unsuitable for boiler use it is still largely used in the construction of feed water heaters owing to its value in resisting corrosion. It is also used for boiler fittings where no great strength is required, and where they are not exposed to the heated gases from the furnace.

Wrought Iron was largely used up to about 1870, and possessed many advantages over any other metal for boiler use. It is strong, tough and fibrous, and combines high tensile strength with great ductility and freedom from brittleness.

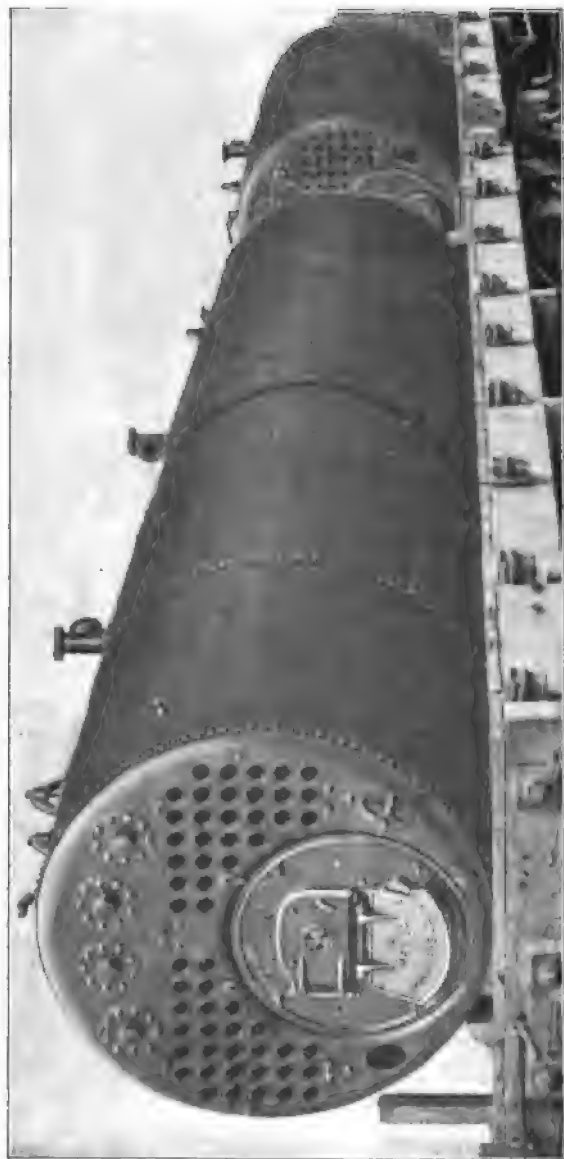
Steel is now accepted as the best metal for all character of boilers, and it has entirely displaced both cast and wrought iron for boiler work. It has great tensile strength, ductility, toughness and freedom from unsoundness. Boiler steel is made by the open hearth process, and contains from .15% to .25% carbon. While a larger per cent of carbon increases the tensile strength of the metal, it **lessens** its ductility.



A Type of a Water Tube Boiler.
Fig. 15.



A Type of a Water Tube Boiler.
Fig. 16.



An Internal Furnace Boiler.
Fig. 17.

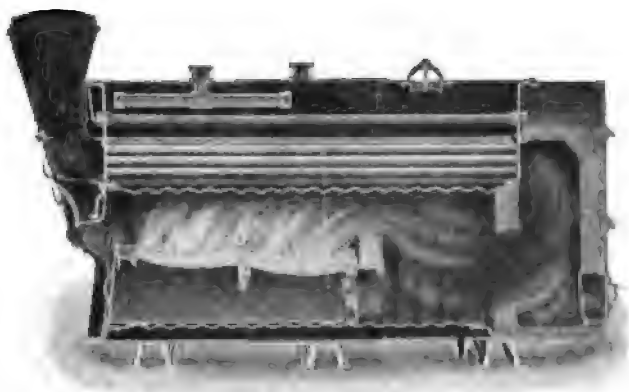
IRON AND STEEL.

It is most important that every one who works around or is in charge of a steam boiler, should know something about the different properties of iron and steel.

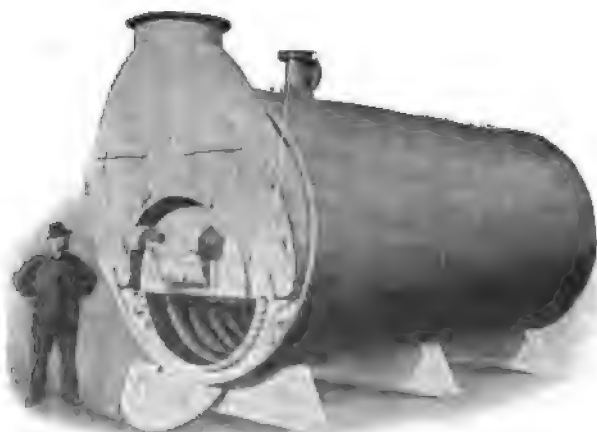
Ingredients.—Commercial iron and steel are metallic mixtures, the chief ingredient of which is the element "Iron," that is, pure iron, of which they contain from 93% to 99%. The difference between iron and steel is principally due to the composition and proportion of the remaining ingredients.

The **Iron Ore** from which both these metals are made contains from 35% to 65% of iron, the balance being oxygen, phosphorus, sulphur, silica, and other impurities. The ore is charged in a blast furnace, mixed with lime stone as a flux and melted down with either charcoal, coke, or anthracite coal as a fuel. The resulting metal obtained is what is commercially known as **Pig Iron**, containing about 93% of pure iron, 3% to 5% of carbon and a trace of silicon, phosphorus, sulphur, etc. This pig iron is used in foundries for the manufacture of iron castings, by simply remelting it in a cupola which does not materially change its chemical composition; the only results being a closer grain and somewhat increased strength.

• In the manufacture of **Wrought Iron** the pig iron is melted in so-called puddling furnaces, by charging about one-half a ton in a furnace, and, while in the molten state, it is stirred up with long iron hooks by the puddler so as to expose every part of the iron bath to the action of the flame in order to burn out the carbon. This is readily done as carbon is nothing more than pure coal.



Section of an Internal Furnace Boiler.
Fig. 18.



The Internal Furnace Boiler Installed.
Fig. 19.

The other impurities will separate from the iron, forming what is known as puddle cinder.

Steel is made either from pig iron, as in the Bessemer and open hearth processes, or, from wrought iron as in the cementation and crucible processes. Steel therefore is nothing more than cast iron or wrought iron with more or less of carbon in them. To make steel from pig iron it is necessary to burn the carbon out of it, and to make it from wrought iron, on the contrary, it is necessary to add carbon to it.

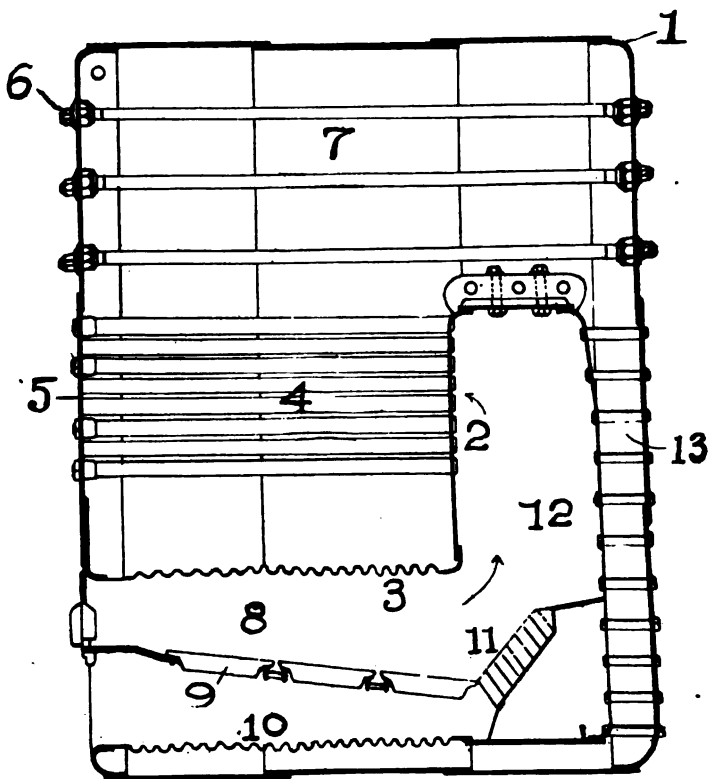
The purer the iron the higher is its melting point. Pig iron melts at 2100 degrees Fahrenheit, steel at 2500 degrees and wrought iron at 2800 degrees.

In the **Bessemer Process** the molten pig iron is put into a large pear-shaped vessel called the "Converter," the bottom of which is double, the inner vessel being perforated with a great number of holes called "tuyeres" to admit air to be forced in under pressure. The molten iron is poured into the converter while lying on its side, then the compressed air is turned into the double bottom as the converter rises to a vertical position. The air has sufficient pressure, usually 20 lbs. per square inch, to prevent the molten metal from entering the tuyeres.

The air passing up through the molten metal burns out the carbon, silicon, etc.

The **Open Hearth Process**, sometimes called "the Siemens-Martin process," is similar to the puddling process, but is on a much larger scale. The furnaces have a capacity from 40 to 200 tons of molten metal, and they are usually heated by gas made from bituminous coal.

The gas and air needed for its combustion are heated



Sectional View of a Marine Boiler.

Fig. 20.

to a high temperature, over 1000 degrees Fahrenheit before entering the combustion chamber, by passing them through regenerative chambers. Owing to this heating of the gas and air a very high temperature can be maintained in the furnace. To the molten metal certain chemicals are added to keep it in a state of agitation, which takes the place of puddling or stirring it.

Cementation Process.—The oldest method of making crucible or tool steel is by the cementation process, in which the wrought iron bars are packed in air-tight retorts with powdered charcoal between the bars. The retorts so filled are then placed into a cementation furnace and kept red hot for several days, during which time the iron will **absorb** about one and one-half per cent of its weight of carbon.

Malleable Castings are produced in just the **reverse** way from the cementation process.

Instead of taking wrought iron and **adding** carbon to them, iron castings are packed in similar retorts with an oxide of iron, usually hermatite ore, and kept red hot for several days, permitting the oxygen of the ore to absorb the carbon in the iron, thus extracting the carbon.

Malleable castings are largely used for boiler fittings where cast iron is not permitted, although the latest requirements of good boiler practice, require all fittings to be of steel.

The material employed in the construction of boiler shells should possess two qualities that are absolutely essential to render them safe.

These qualities are **Tensile strength** and **ductility**.

Tensile Strength.—By tensile strength is meant the amount of force which, steadily and slowly applied in

a line with the axis of a metal, just overcomes the cohesion of the particles, and pulls it into separate parts

Ductility.—This is the property of a metal which permits it to be extended by a pulling or tensile force and remain extended after the force is removed. The greater the permanent extension, the more ductile the metal.

The tensile strength must be sufficient to withstand the stress due to the pressure of the steam, and the ductility must be sufficient to prevent cracking by unequal expansion and contraction from frequent heating and cooling.

The one metal which possesses these two properties above all others, is **steel**, and it is therefore the metal universally adopted for the construction of all boiler shells, and for most of the fittings.

Requirements.—The manufacturers of boiler plate are required to stamp the tensile strength of the plate at the corners of each sheet or plate, about 4 inches from its edge, and at or near the center of the plate; also the name of the manufacturer and the place where the plate is manufactured. Each plate has a coupon attached to be cut off and used for testing the material. Every plate is numbered and recorded, and in this way a complete oversight is kept of every plate used in the construction of a boiler from the time the iron ore is melted to the final inspection of the boiler when completed and ready to be fired.

STANDARD SPECIFICATIONS FOR SPECIAL OPEN-HEARTH PLATE.

Adopted by the Assn. Am. Steel Manufacturers, July 17, 1896.

Steel shall be of four grades—**Extra Soft, Fire Box, Flange or Boiler, and Boiler Rivet Steel.**

Extra Soft Steel.—Ultimate strength, 45,000 to 55,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 28 per cent. Cold and Quench bends, 180 degrees flat on itself, without fracture on outside of bent portion. Maximum phosphorus, .04 per cent; maximum sulphur, .04 per cent.

Fire Box Steel.—Ultimate strength, 52,000 to 62,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 26 per cent. Cold and Quench bends, 180 degrees flat on itself, without fracture on outside of bent portion. Maximum phosphorus, .04 per cent; maximum sulphur, .04 per cent.

Flange or Boiler Steel.—Ultimate strength, 52,000 to 62,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 25 per cent. Cold and Quench bends, 180 degrees flat on itself, without fracture on outside of bent portion. Maximum phosphorus, .06 per cent; maximum sulphur, .04 per cent.

Every finished piece of steel shall be stamped with the melt number.

Rivets and Riveting.—In the construction of a boiler, the following is the usual order of operations in the shop: (1), the flat plates from the rolling mill are cut or sheared to the desired size; after being sheared they are placed in a machine that smooths the rough edges. Next the rivet holes are punched, or drilled, at the required distances near the edge of the plate. The plate is then passed through large rolls and bent to a cylindrical form in such a way that the corresponding rivet holes in the two edges come directly opposite each other. One or two bolts are put through these holes

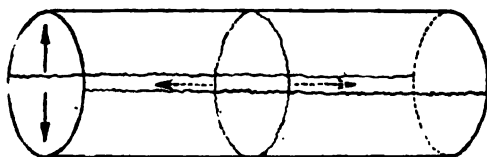
to hold the edges together, and the plate is then riveted. The heads are next flanged and riveted in place. After the riveting is completed, the tubes or flues are put in and expanded, the stays and braces are put in place, and the boiler is ready to be installed.

Riveting.—Rivets are used both in the longitudinal and the girt, or circular, seams of the boiler; but it is the longitudinal seams which require the most strength to hold them together, as the pressure upon the shell of the boiler is far greater than on the heads, there being much more surface exposed to the pressure of the steam.

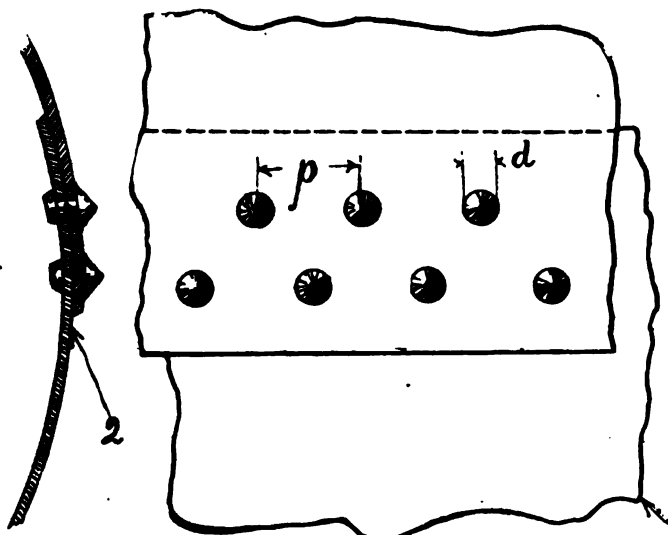
Internal Forces.—The cylindrical shell of a boiler is subjected to two internal forces which tend to rupture it, as is illustrated in Fig. 21. One force, indicated by the two arrows (1), act in the direction of the **length**, which tends to tear the shell as shown by these arrows. This stress must be borne by the **heads** of the shell, and is therefore upon the circular or girt seams. The other force, indicated by the arrows (2), act perpendicular to the axis of the first force, and tend to rupture the boiler in a longitudinal plane, that is, **lengthwise** of the shell. This stress is borne by the **shell** of the boiler, and is therefore upon the longitudinal seams or joints.

These two forces are opposed by the strength or tenacity of the material of which the shell is composed.

It can be shown by mathematicians that the magnitude of the force tending to rupture the shell in a longitudinal plane, that is, along the longitudinal seams or joints, is equal to the internal diameter of the shell multiplied by the length multiplied by the pressure. It has been further proved that the circular or girth seam of a boiler need only be single riveted, while the longi-



Stresses on Boiler Shells.
Fig. 21.



A Lap Joint.
Fig. 22.

tudinal seams must be double riveted, triple riveted, or even quadruple riveted. When the longitudinal seams are made extra strong, as when they are made butt joints with two cover plates and triple riveted, the girt seams are then usually made double riveted as an extra precaution.

Stresses.—Riveted joints may fail in several ways: First, by the rivets shearing. **Second**, by tearing the plate in a section between the rivets. Third, by the cracking of the plate between the rivet holes and the edge of the plate. Fourth, by crushing the plate or rivets where they are in contact. All stresses upon boilers may therefore be resolved into three kinds, viz.: Tensile, compressive, and shearing.

Shearing Strength.—By shearing strength is meant that force which, if steadily and slowly applied at right angles, or nearly so, to the line of the axis of the rivet, causes it to separate into parts, which slide over each other, the planes of the surface at the point of separation being at or about right angles to the axis of the rivet.

Strength of Boiler.—The strength of the longitudinal seam in all forms of boiler shells, determines to a great extent the pressure which the boiler is capable of carrying with safety. It is the object therefore of all boiler constructors to make this seam as strong as possible. To do this there are numerous forms of riveting and constructions of joints.

Rivets.—Rivets are usually made by forging from round iron bar or mild steel, with a cup, conical or pan-shaped head. The cylindrical part, called the shank, is a little smaller and has a slight taper. The conical head

rivet is the form most generally used in boiler construction.

Formerly all joints of boilers were riveted by hand, but riveting is now done almost exclusively by machinery. If done by hand, a red hot rivet is inserted in the hole and the second head formed by two riveters using hammers.

The disadvantages of hand riveting was slowness and a tendency to form a shoulder before the rivet filled the hole. The shearing strength of steel rivets is about 45,000 lbs. per square inch, and of iron rivets about 40,000 lbs. per square inch.

DESIGNS OF JOINTS AND STAYS.

Riveted Joints.—There are various forms and strengths of riveted joints.

Lap Joints.—If one plate overlaps another, as shown in Fig. 22, it is known as a lap joint. If a single row of rivets is used it is called a single riveted lap joint. Such a joint has about 56 per cent of the strength of a solid plate. If another row of rivets is added, it is called a double riveted lap joint. Such a joint has about 70 per cent of the strength of the solid plate. If still another row of rivets is added, it is called a triple riveted lap joint. Such a joint has about 75 per cent of the strength of the solid plate. The riveting in these joints may be either what is known as chain riveted, i. e., where the rivets are in straight lines and immediately opposite each other, or, zig-zag riveted or staggered, as shown in the above cut.

In zig-zag or staggered riveting, the rivets of one row are opposite the spaces of another row.

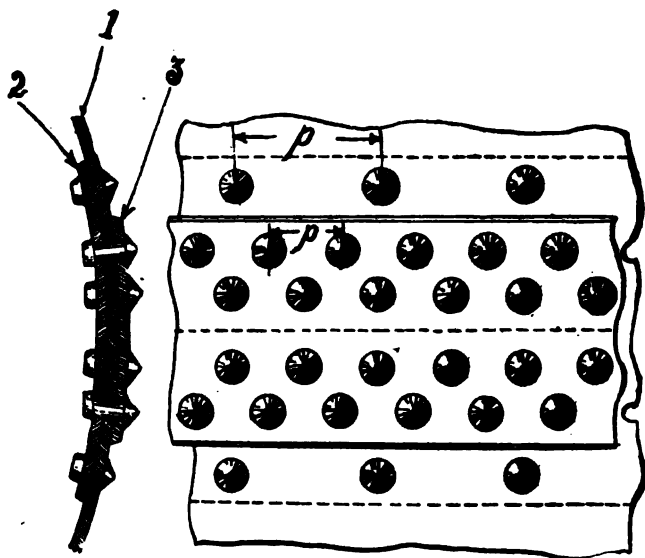
Pitch of Rivets.—In Fig. 23, the distance p represents the pitch of the rivets, by which is meant the distance between the centers of the rivets. The diameter of the rivet hole is indicated by the space d .

Butt Joints.—If the two plates are kept in the same plane and a cover or butt strap riveted over the joint, it is then called a butt joint. If an inside butt strap is also added, it is called a double butt joint, as illustrated in Fig. 23. A single butt joint is about equal in strength to a lap joint having but one row of rivets, but a double butt joint is much stronger. In Fig. 23 is shown a standard triple riveted butt joint with an efficiency of 88 per cent. See Fig. 23 on page 76.

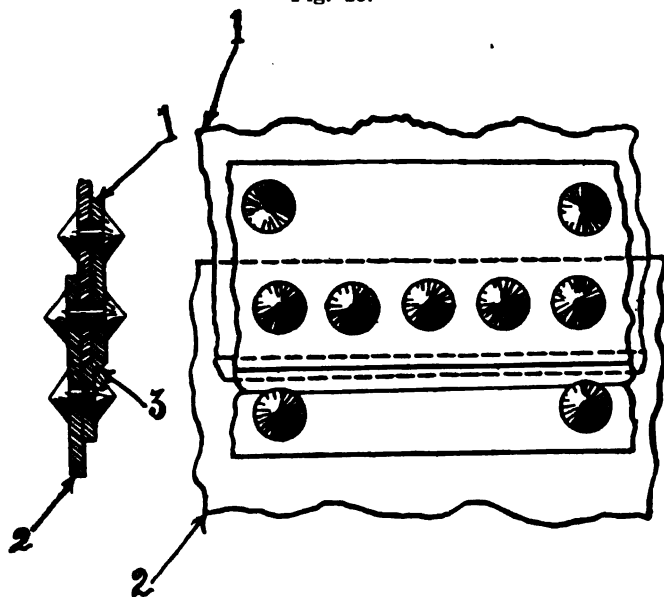
Locomotive Joints.—Fig. 24 illustrates the locomotive joint, a combination of the lap and butt joint, which joint is used mostly for locomotive work, but has found little favor for stationary work.

Lap joints are used for the circular or girth seams, and the butt joints for the longitudinal seams. The lap joint is rarely used for longitudinal seams, although until recently it was the most popular form of joint, even for high pressure boilers.

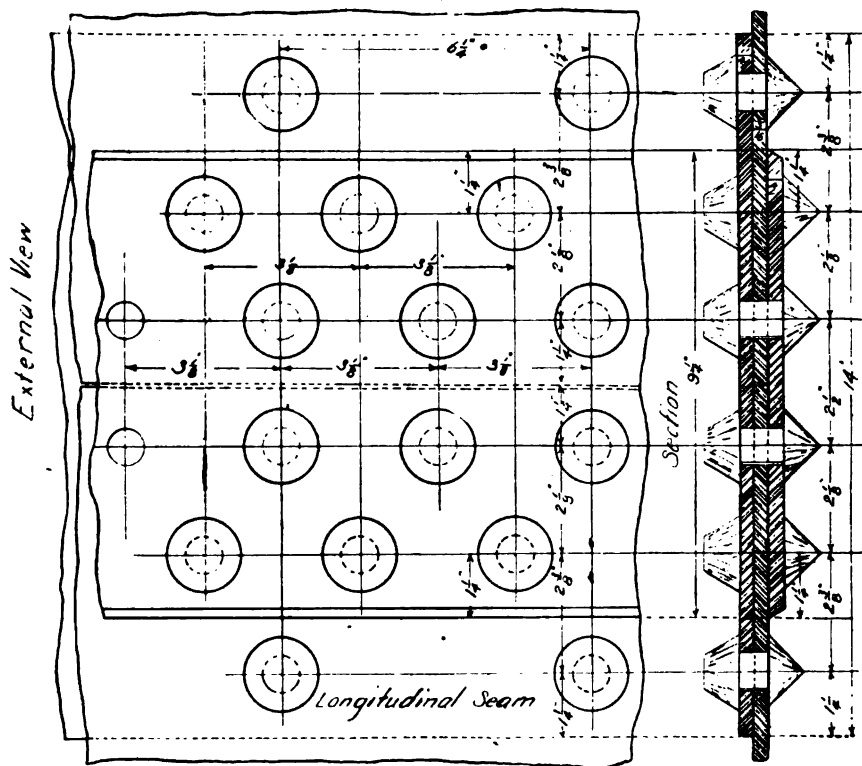
Regulations.—The lap joint is now regarded with such disfavor that both the cities of Chicago and St. Louis have within the past two years prohibited its use in the construction of all boilers to be used in those cities, they requiring the use of butt joints on all longitudinal seams. The above cities require all boilers having cylindrical shells or drums of more than 42 inches in diameter, and carrying more than 15 lbs. steam pressure to the square inch, to have all longitudinal seams butted and held together by straps riveted over them. Where single butt straps are used, they must not be less in thickness than the shell plates, and where double butt straps are used, each strap or cover must be not less than five-eighths of the thickness of the shell plate.



A Butt Joint.
Fig. 23.



A Locomotive Joint.
Fig. 24.



Standard Triple-Riveted Butt Joint.
Efficiency 88 %. Rivets 11-16". Holes $\frac{3}{4}$ ". Pitch $3\frac{1}{8}"-6\frac{1}{4}"$.
Fig. 23.

The above regulation practically prohibits the further use of the lap joint in the construction of all boilers to be built for use in those cities. As about 80 per cent of all boilers now in use are made with a lap joint, it will make a most radical change, but one required for the public safety, owing to the rapid increase in the amount of pressure carried on boilers. This is largely due to the growth of electricity, high speed engines, and the increased demands of manufacturers.

The principal objection to the further use of the lap joint, is the impossibility to detect, either by an internal or external inspection of the boiler, any fracture or crack occurring along the inner or outer lap.

Since the crack, or fracture, does not extend through the metal a leak is not caused, and being under the edge of the lap it becomes almost impossible to detect it.

Again, the form of the boiler takes a distinct departure from a true circle where the seams are lapped, which is not considered good practice, in that, in forcing the edges together the fibre of the metal is likely to be injured.

This is not the case with the butt joint as the true circle of the sheets is maintained, without it being necessary to sledge over the edges of the plate as is necessary in the lap joint. If the boiler plate is very ductile it may never give any trouble, but if it is brittle it will be all the more liable to sustain injury in this mauling process, and it is only a question of time before it will yield and crack from the repeated expansion and contraction of the shell.

The crack usually develops on the inside of the joint, where it cannot be discovered even by the closest

form of inspection. While it is true that the interior of a butt strapped joint is equally inaccessible to inspection, there is far less liability of such a crack developing.

As a boiler is no stronger than its weakest point, and as the efficiency of the lap joint has been clearly shown to be much less than that of the butt joint, and in view of the fact that probably 70 per cent of all boiler explosions occur from the use of the lap joint, it is only proper that its further use should be condemned.

In a 72-inch boiler with 90 lbs. pressure and rivets pitched $2\frac{1}{4}$ inches, there would be a force of over $3\frac{1}{3}$ tons pulling on a strip $2\frac{1}{4}$ inches wide, being one rivet in each row of a double lap joint. From this it can be seen how high must be the efficiency of the joint.

Safe Working Pressure of Boilers.—No rule to determine the safe working pressure of a boiler can fill modern requirements which is not based upon the **efficiency of the joint**. As the strength of all riveted joints employed in steam boilers is less than that of the solid plate, its strength must be the chief factor in all calculations or rules for determining the safety of boilers.

The rule adopted by the most modern boiler makers and inspectors, and the one which is undoubtedly the safest rule, is as follows, viz.:

Rule.—From the distance from center to center of the rivets, subtract the diameter of rivet hole. Divide the remainder by the first number.

This result gives the percentage of the solid plate.

Next, multiply the tensile strength of plate by its thickness in parts of an inch, and this product by the percentage of solid plate.

Divide this result by one-half the diameter of the boiler, and the quotient will be the bursting pressure per square inch.

Divide this by the factor of safety, and it will give the **maximum safe working pressure**.

Factor of Safety.—Owing to the great danger from steam boilers, every precaution must be taken for their safety, and a wide margin is therefore left between the bursting pressure of a boiler, and the actual working pressure which will be permitted on same. Defects in material and construction cannot always be detected, even with the most careful inspection, and this margin, or, the amount in which the bursting pressure exceeds the working pressure, is called the factor of safety, and is made sufficiently large to cover any possible defects.

When the material and construction is only moderately good the factor of safety should be made as high as 6, which means only one-sixth of the actual bursting pressure will be permitted on this boiler. If the material and construction are good and the boiler will probably be well cared for by competent men, the factor of safety is then placed at $4\frac{1}{2}$ or 5. Most of the large cities of this country use a factor of 4, though St. Louis uses $4\frac{1}{2}$ and Philadelphia a factor of 5.

Example of Application.—What is the bursting pressure, per square inch, on a boiler 54 inches diameter, plates $\frac{5}{16}$ inch thick, tensile strength 50,000 pounds per square inch, pitch of rivets $3\frac{1}{8}$ inches, diameter of rivet holes $\frac{3}{4}$ of an inch?

$$\begin{array}{rcl}
 3\frac{1}{8} & \text{equals} & 3.125 \\
 5/16 & \text{equals} & .3125 \\
 3/4 & \text{equals} & .750
 \end{array}$$

$$\begin{array}{rcl}
 3.125) & 2.37500 & (.76 \text{ equals percentage of joint.} \\
 & \underline{2.1875} &
 \end{array}$$

$$18750$$

$$18750$$

54 inches divided by 2 equals half diameter of boiler.

$$\begin{array}{rcl}
 50.000 & \times & .3125 \text{ equals } 15625.000 \\
 15625.0000 & \times & .76 \text{ equals } 11875.000000 \\
 11875.000000 & & \text{equals } 439.81 \text{ pounds, or bursting} \\
 & & \text{pressure.}
 \end{array}$$

27

$$\begin{array}{rcl}
 \text{Factor of safety } 4.5) & 439.81 & \\
 & \underline{\hspace{1cm}} &
 \end{array}$$

97.7 lbs. equals maximum work-
pressure.

The rule adopted by the U. S. Government is not given here, as it does not meet modern requirements for stationary work; and, in fact, is antiquated even for marine work.

Staying.—If a boiler were spherical it would require no stays, but the flat ends or surfaces in all boilers must be stayed, otherwise the internal pressure would bulge them out and tend to force them into a spherical shape. The first and most important point in staying, is to have a sufficient number of stays so that they will entirely support such flat surfaces. The second requirement is to have them so arranged as to allow a free circulation of the water in the boiler. The third require-

ment, and naturally the most important, is to so arrange the stays as to permit a free and thorough inspection of the boiler.

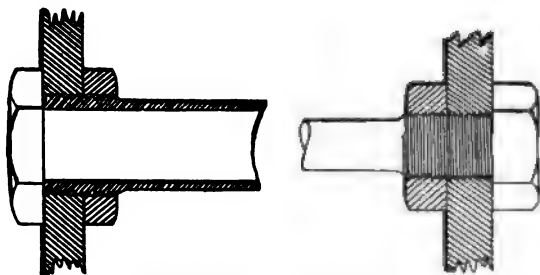
In the ordinary fire tube boiler the principal surfaces to be stayed are: the flat ends, crown sheets and combustion chamber.

One of the most common forms of stays is shown in Fig. 25.

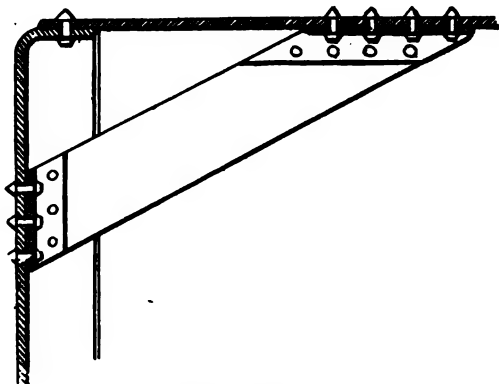
Through Brace.—This stay is a plain rod passing through the steam space and having the ends fastened to the heads. The ends are fastened in various ways, the simplest and best way being to have nuts on both sides of the plate, as shown in the above figure.

Gusset Stay.—This stay is shown in Fig. 26, and consists of an iron or steel plate, which is placed between angle irons which are securely riveted to the head and shell of the boiler. The plate is then riveted to the angle irons. These stays are not generally used in this country, owing to their absence of flexibility which often induces grooving and cracking of the head plates.

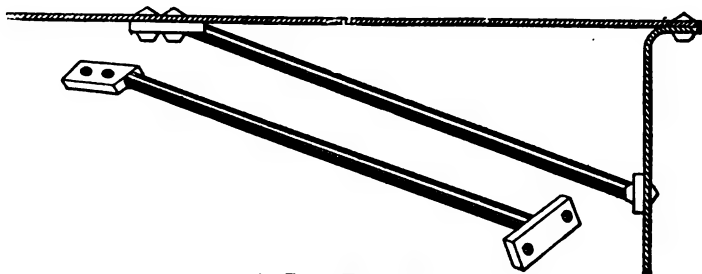
Crow-Foot Stay.—The crow foot stay is the most common method used in this country for supporting the heads of stationary boilers. This stay is shown in Fig. 27, and consists of a round bar on one end of which is welded the crow foot, the other end of the bar being bent as shown in the cut. The crow foot is riveted to the head, and the bent end to the shell. An improved form of crow foot brace is the McGregor brace, which consists of a single piece of sheet steel, bent in one heat. Being weldless, it will bear a much greater strain than the welded crow foot brace. In the Huston crow foot brace, the crow foot is formed by flanging the plate of which the brace is formed.



Through Stay and Brace.
Fig. 25.



A Gusset Stay.
Fig. 26.



A Crow-Foot Stay.
Fig. 27.

Diagonal Brace.—This brace, as shown in Fig. 28, consists of a plain rod connected to angle irons by means of split pins. This brace is not in general use.

Direct Stays.—For large boilers carrying high pressure, the most direct and strongest way of supporting the heads is to use through stay rods. Fig. 29 is sectional view of a boiler, showing stays and braces.

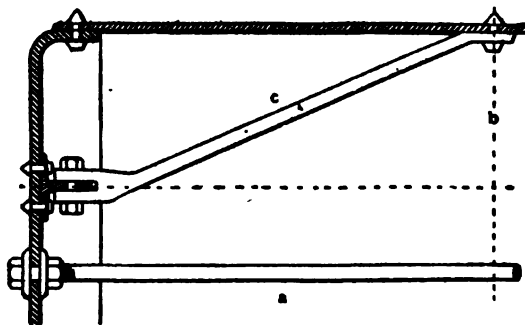
TUBES AND FLUES.

Use.—Tubes and flues are used for increasing the heating surface of boilers, though they also add strength to the boiler and assist in the quick raising of steam. The tubes when used for increasing the heating surface are made of charcoal iron or soft steel, and are either lap welded or solid drawn. When the tubes exceed 6 inches in external diameter they are called flues. While pipe is designated by its **internal** diameter, the size of tubes for boiler work is designated by their **external** diameter.

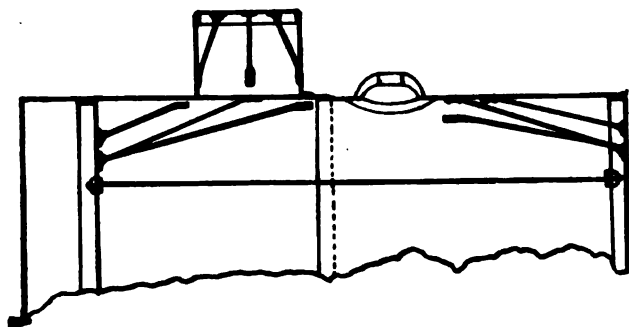
Dimensions.—Table No. 1 gives the standard dimensions of tubes in most common use in steam boilers.

Number.—The number of tubes used in return tubular boilers vary with the size of the boiler and the conditions under which the boiler must work. The number of tubes usually put in return tubular boilers has been heretofore given.

Boiler tubes are usually **expanded** into the tube sheets, except stay tubes, which are screwed in and secured by lock nuts on both sides of the tube sheet. Fig. 30 illustrates how the tube ends are fastened in the tube sheets. The tubes are first expanded by means of a tube expander, and then beaded over so as to make them se-



A Diagonal Stay.
Fig. 28.



Section of Boiler Showing Stays and Braces.
Fig. 29.

cure. The manner of fastening the tube in the tube sheets varies greatly, but the method described above is the one most generally used.

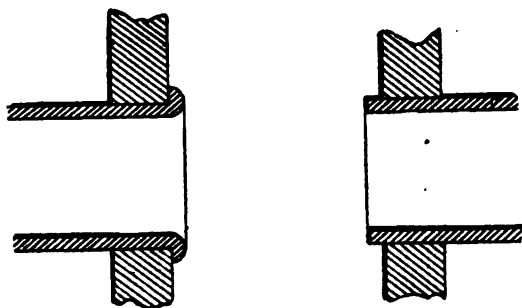
Flues are usually riveted to the flanged heads of boilers as is shown in Fig. 31.

GRATE AREA, HEATING SURFACE AND TUBE AREA.

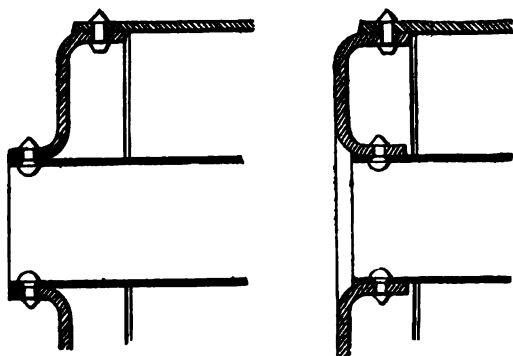
Basis.—The grate area, or grate surface, depends on the rate of combustion, the quantity of water to be evaporated per pound of fuel and the total weight of steam evaporated per hour. It can be seen from this how important it is that there should be sufficient grate area for the burning of fuel in a boiler furnace. To determine the necessary grate area to be placed under a boiler, it is only necessary to know the amount of steam the boiler will be called upon to generate to do its work.

For example, suppose that a plant requires 6000 pounds of steam per hour. Assume that 16 pounds of coal are burned per square foot of grate surface per hour, and that each pound of coal will evaporate 6 pounds of water. Then, it follows that the grate surface required would be $6000 \div 16 \times 6$ equals 62.5 square feet of grate surface. It would be necessary to divide this grate surface among several furnaces, since a grate longer and wider than six feet cannot readily be fired.

Heating Surface.—The heating surface of a boiler is that portion of the surface which is exposed to the action of the flames and hot gases. This includes only so much of the shell as is below the line of brick work which closes in the sides of the boiler. This line is called the **fire line** of the boiler, and is always deter-



Tubes as Secured to Head.
Fig. 30.



Flues as Secured to Head.
Fig. 31.

mined by the closing in of the side walls, as above this line the shell of the boiler cannot come in contact with the flames from the furnace or the heated gases. The exposed heads of the shell, and the **interior** surface of the tubes or flues constitute the remainder of the heating surface. The above applies only to shell boilers, the heating surface of a water tube boiler being somewhat different. In a water tube boiler the heating surface comprises that portion of the shell or steam drum below the brick work, the outer surface of the headers, and the **outer** surface of the tubes, as the interior surface of the tube is filled with the water to be evaporated.

To find the heating surface of a return tubular boiler the following rule must be used:

Rule.—Multiply two-thirds the circumference of the shell in inches by its length in inches; multiply the number of tubes by the length of the tube in inches and by its circumference; add to the sum of these products two-thirds of the area in square inches of the two heads or tube sheets; from this sum subtract twice the area of all the tubes and divide the remainder by 144; the result is the heating surface in square feet. Some rules call for only one head, but the better practice is to take both heads.

From this it can be seen that the greatest part of the heating surface of tubular boilers is furnished by the tubes, and not by the direct heat of the furnace against the shell as is generally supposed.

Ratio of Heating Surface to Grate Area.—In order to obtain the best results from a boiler, it is necessary that the temperature of the heated gases should pass into the chimney at as low a temperature as possible, as has been shown. A large amount of heating surface is therefore

LAP-WELDED CHARCOAL-IRON BOILER TUBES

TABLE OF STANDARD DIMENSIONS

Diameter	Circumference		Wire Gauge	Thickness, Inches	Transverse Areas			Length of Tube per Sq. Foot of		Nominal Weight per Foot, Pounds
	External, Inches	Internal, Inches			External, Sq. Inches	Internal, Sq. Inches	Metal, Sq. Inches	Ex. Surf., Feet	Int. Surf., Feet	
1	3.56	3.142	15	.072	2.689	785	.575	3.819	4.462	.71
1 1/4	1.108	3.927	15	.072	8.476	1.227	.266	3.056	3.453	.89
1 1/2	1.884	4.712	14	.083	4.191	1.767	.399	2.547	2.993	1.24
2	1.56	5.498	13	.095	4.901	2.405	.494	2.193	2.448	1.66
2 1/4	1.81	6.283	13	.095	5.686	3.142	.569	1.909	2.11	1.91
2 1/2	2.06	7.069	13	.095	6.472	3.876	.643	1.698	1.854	2.16
2 3/4	2.302	7.854	12	.109	7.189	4.909	.819	1.528	1.674	2.75
3	2.532	8.639	12	.109	7.954	5.94	.906	1.389	1.509	3.04
3 1/4	2.782	9.425	12	.109	8.74	7.069	.99	1.273	1.373	3.33
3 1/2	3.01	10.21	11	.12	9.466	8.296	1.18	1.173	1.26	3.96
3 3/4	3.26	10.946	11	.12	10.241	9.821	1.374	1.091	1.172	4.28
4	3.51	11.781	11	.12	11.027	10.645	1.569	1.018	1.066	4.6
4 1/4	3.782	12.666	10	.134	11.724	12.566	1.827	.965	1.024	5.47
4 1/2	4.232	13.4	10	.148	13.296	16.904	1.888	.849	.902	6.17
5	4.704	15.766	9	.165	14.778	19.685	2.256	.764	.812	7.58
6	5.67	18.85	8	.185	17.813	23.274	3.026	.637	.673	10.16
7	6.67	21.991	8	.195	20.964	28.496	3.543	.546	.578	11.9
8	7.67	25.133	8	.205	24.096	34.942	4.062	.477	.498	13.05
9	8.64	28.274	7	.218	27.143	40.266	4.588	.424	.442	16.76
10	9.594	31.416	6	.238	30.14	45.829	5.116	.382	.398	20.99

Table No. 1.

necessary to permit the hot gases time and opportunity to give up their heat to the water before passing up the chimney. The higher the rate of combustion, the greater should be the heating surface of the boiler.

In every day work this ratio between the heating surface and grate area varies between 45 and 50, which means that for every square foot of grate surface there should be from 45 to 50 square feet of heating surface.

For example, should the dimensions of a furnace be 6 feet by 6 feet or 36 square feet, then the heating surface of the boiler should be from 1600 to 1800 square feet.

Tube Area.—Since the products of combustion, or heated gases must pass through the tubes or flues, their combined cross sectional area, which is called the tube area, must be large enough to allow the entire column of heated gases to pass through them, with little friction and without interfering with the draft. But there must be sufficient friction to retard the flow of gases sufficiently to allow them to part with a greater part of their heat, and hence it can be seen that the tubes must be made neither too large or too small, but proportioned with the greatest care. For bituminous coal, the tube area should be from $1/6$ to $1/7$ the area of the grate surface, and for anthracite coal, from $1/8$ to $1/9$ the area of the grate surface.

DOMES, STEAM AND MUD DRUM, MAN AND HAND-HOLE PLATES.

Use.—Domes are placed on cylindrical boilers for the purpose of increasing the steam space, and also for the purpose of drying the steam.

Domes are by no means necessary on stationary boilers, which is shown, by the constantly increasing number of boilers being built and successfully operated without them. They are, therefore, by no means a necessary attachment to a boiler, and it is only a question of time before their use will be entirely dispensed with by boiler makers. While they add some steam space, it is not enough to justify the extra cost of the dome, and also, the placing of a dome on a boiler weakens the shell to a considerable extent. The principal advantage claimed for the dome is that when the water level is carried too high, and the boiler is at the same time heavily fired, the danger of water entering the steam pipe is less than in a boiler without a dome. This is no real advantage, as a boiler properly constructed and operated may be forced far beyond its rated capacity and still furnish dry steam to the engine. As almost all boilers are sold with a guarantee of at least 25 per cent above their rated capacity, it can be seen what little real advantage is the placing of a dome on a boiler for this purpose.

Steam Drum.—Instead of a dome, a steam drum should be used. This drum consists simply of a cylindrical vessel connected to the shell of the boiler. When several boilers are set so as to form a battery, they are generally connected to one such drum, called the header, which is common to all the boilers. When each boiler has its own furnace, there should be a stop valve between each boiler and this drum or header, so as to permit the boiler to be cut out of service when not in use.

The strength and safety of these steam drums, or headers, should be determined by the rules governing the strength of boiler shells. They should also be as rigidly inspected as the boiler itself.

Mud Drum and Blow Off Apparatus.—The object of a mud drum is to collect the sediment which is precipitated from the water in the boiler. When used, it is placed underneath the boiler and near the rear end of same, being attached to the boiler by a suitable nozzle. It must be suspended in such a manner that no portion of the weight of the boiler comes upon it.

In boilers equipped with mud drums, the feed water is frequently introduced into the boiler through this drum, which has the advantage of permitting the feed water to be heated before entering the boiler, but the proper function of this drum is not to act as a feed water heater, but to collect the sediment in the water so that it can be more easily removed from the boiler through the blow-off pipe. In Fig. 8 is shown the location and dimensions of an ordinary steam drum attached to a horizontal boiler.

Blow Off Pipe.—This blow off pipe serves for the double purpose of emptying the boiler, and of discharging the sediment that collects. Each boiler must be provided with such a pipe that enters the boiler at its lowest point, or attached to the mud drum, when a boiler is provided with one.

This blow off pipe when exposed to the heated gases, must always be protected by a sleeve made of pipe, or by being bricked in, or protected by asbestos covering. The mud drum must also be protected from the heated gases by a brick wall built around it, leaving a small space between it and the wall.

Obsolete.—The use of a mud drum is fast becoming obsolete, and like the steam dome it will soon be entirely discarded.

Blow-Off.—The blow-off apparatus must be given most careful attention as the pipe is apt to clog with scale and sediment. The use of globe valves on the blow off pipe is therefore objectionable, as such valves do not open freely, and as a piece of scale or sediment may get between the valve and its seat. As a result, the water would leak out of the boiler unperceived. Modern practice requires plug-cocks packed with asbestos, which removes the objections above stated to the use of globe valves.

Surface Blowoff.—Boilers are sometimes fitted also with a surface blowoff, which is a pipe to which is attached a scoop shaped vessel placed three or four inches below the water level. The pipe is provided with a valve or cock. To operate same it is only necessary to open **wide** the valve or cock, which causes a rapid discharge through the pipe, the force of which draws the sediment into the scoop, and discharges it through same.

Man-Hole and Hand-Hole.—The man-hole is placed in the shell of a boiler to permit access to the interior of same for cleaning, repairing and inspecting it. They are usually placed either in the heads or in the top of all horizontal shell boilers, sometimes in both places. In water tube boilers, man-holes are usually placed in the upper drum, and either a man-hole or a hand-hole in the mud drum. The size of the standard man-hole is 11x15 inches, the longer diameter being placed at right angles to the axis of the shell.

Construction.—Hand-holes are constructed similarly to man-holes, the only difference being that they are made much smaller, permitting only the hand and arm to be inserted through them, and therefore, require only one yoke and one bolt to hold them in place.

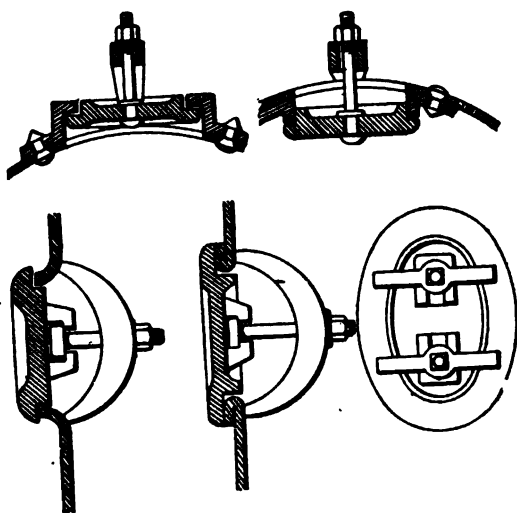
Both the man-hole and hand-hole should be sufficiently strong to sustain the stresses not only due to the direct steam pressure upon them, but also the stresses from the plate. In order to do this they are always reinforced, that is a forged or reinforcing ring or rings is placed around the section that is cut out of the shell, and securely riveted to the shell. In Fig. 32, the construction of man and hand-holes is shown, together with the cover plates and yoke which close them. Man-holes and hand-holes are made elliptical to allow the cover to be passed through the hole.

SAFETY ATTACHMENTS ON BOILERS.

Safety Valve.—By far the most important attachment on a steam boiler is the safety valve. It is attached to the boiler to prevent the steam pressure rising above a designated point, which point is usually the maximum safe working pressure of the boiler. The necessity of a safety valve on every steam boiler has always been recognized, even from the incipency of the boiler. One of the first boilers ever constructed was supplied with one of these necessary attachments.

When a boiler generates steam faster than the engine can use it, it is evident that a large quantity of steam must be continually forced into the confined steam space of same. This causes the steam pressure to continue to rise until an explosion takes place, unless some means of relief is afforded. It is the sole duty of the safety valve to prevent this increase of pressure above a dangerous point.

Construction.—Its construction is very simple, consisting of a plate or disk fitted over a hole in the boiler shell. This plate or disk is held in its place in one of three ways. (1) By a dead weight, (2) by a weight on



Construction of Manhole and Handhole.
Fig. 32.

a lever, (3) by a spring. The weight or spring is so adjusted that when the steam pressure reaches the designated point, the disk or plate is raised from its seat, permitting the surplus steam to escape through the opening in the shell.

Safety valves are designated from the way this plate or disk called the valve, is held in its place.

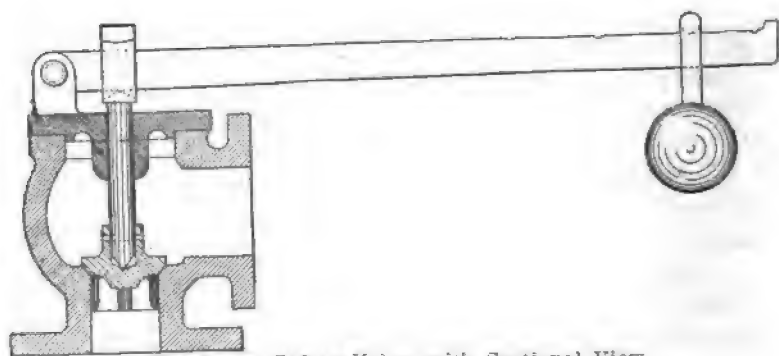
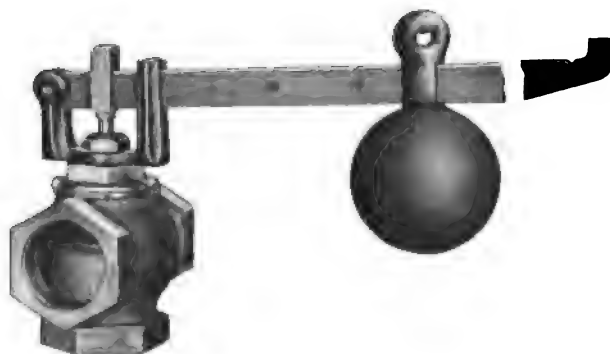
Dead Weight Safety Valve.—This form of safety valve is not used in America, owing to its inconvenience, since the high steam pressure now universally used would require such an extremely heavy weight to be placed on the valve that its use would be impractical. The only thing that can be said in their favor is that it is difficult to overload them, owing to the heavy weights to be handled.

Lever Safety Valves.—This form of safety valve is shown in Fig. 33, and is the most popular valve used in this country. The valve is held to its seat by a weighted lever. The weight used on the lever is easily adjusted along the lever, so that the valve may be set to blow off at any desired steam pressure without trouble.

Spring Safety Valve.—These valves are used on locomotives, and are also in general use upon stationary boilers.

The valve is held to its seat by a spring acting either directly on it, or on a short lever. This valve is illustrated in Fig. 34, and will be more fully described in a later chapter. Its advantage over the lever valve is its adaptability to any character of work, the use of the lever valve, on account of the lever and suspended weight, being confined exclusively to stationary work.

Area of Safety Valve.—The U. S. Government rule is the most generally used rule for finding the proper



The Lever Safety Valve, with Sectional View.
Fig. 33.

area of a safety valve, though there are several rules in general use which differ considerably in the results obtained.

The area of the valve must be sufficiently large to discharge the steam as fast as it can be generated by the boiler.

The U. S. Government rule is based upon the area of the grate surface, it being as follows, viz.:

For a **lever valve**, allow one square inch of area of valve for every two square feet of area of grate;

For a **spring loaded safety valve**, allow one square inch of area of valve for every three feet of area of grate.

THE STEAM GAUGE.

The steam pressure in a boiler is measured in pounds per square inch. This pressure is the working steam pressure above the atmospheric pressure, which is about 14.7 pounds per square inch. Steam gauges are graduated to indicate the steam pressure **above** the pressure of the atmosphere, and should therefore stand at zero when the pressure is off the boiler; and should indicate the exact blowing off pressure when the boiler is in use and the safety valve is in action.

Working Pressure.—When we say that a boiler is working at 60 pounds pressure, we mean that the gauge pressure is 60 pounds to the square inch; that is, the pressure in the boiler is 60 pounds above the atmosphere pressure.

Absolute Pressure.—This is the pressure above vacuum, as is called a space entirely devoid of matter. Therefore, to find the absolute pressure on a boiler which has 60 pounds gauge pressure on same, the atmospheric

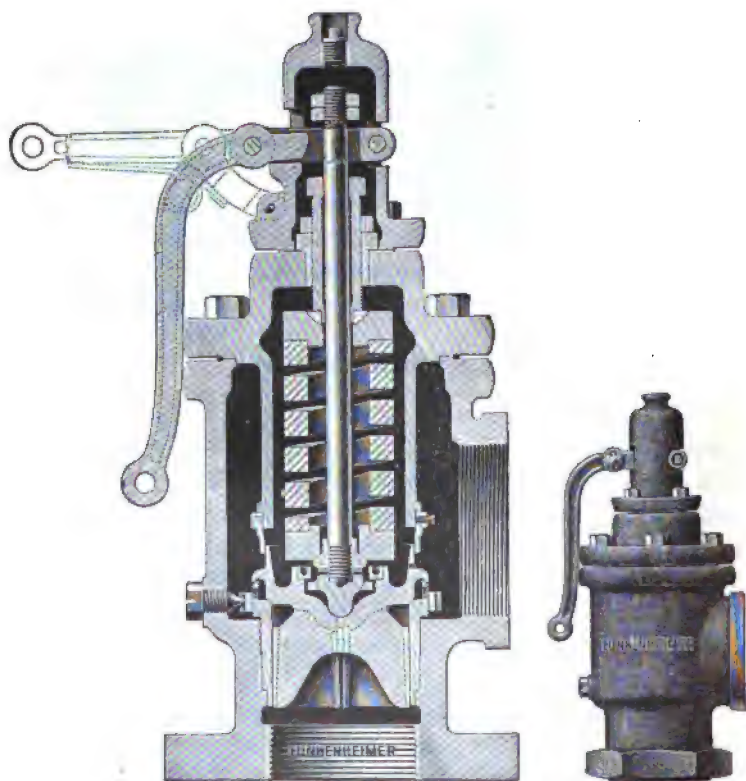


Fig. 34.
Spring or Pop Safety Valve.

pressure must be added to the gauge pressure, which would make the absolute pressure on this boiler about 74.7 pounds per square inch.

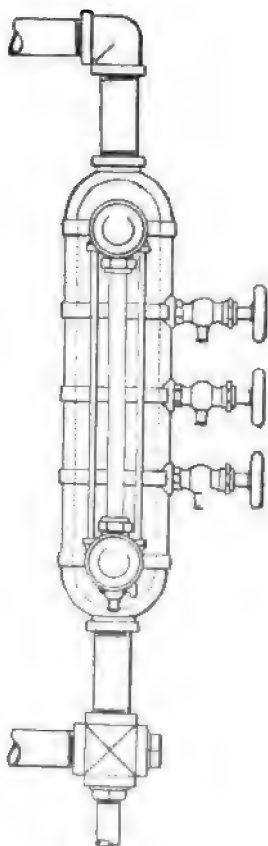
The atmospheric pressure varies with the altitude, that is with the distance above the sea level, the atmospheric pressure at sea level being 14.7 pounds per square inch.

Connection.—The steam gauge should be connected to the boiler in such a manner that it cannot be injured by the heat from same, or by rough usage, as, both for safety and economy, it should always regulate **accurately** the steam pressure within the boiler. To prevent injury from heat, a syphon, which is shown in Fig. 35 together with an ordinary steam gauge, is placed between the gauge and the boiler. This syphon soon becomes filled with condensed steam which protects the spring of the steam gauge from the injury the steam would otherwise cause.

In a battery of boilers, each boiler should have a separate steam gauge. This gauge must always be connected **directly** to the boiler, and not to the steam pipe or other boiler fittings..

The steam pressure gauge which is now almost universally used was invented by M. Bourdon, and its construction will be fully described in a later chapter.

This gauge operates on the principle that a flattened curved tube closed at one end, tends to become straight when subjected to an internal pressure. The pressure when used in connection with the steam boiler, is the steam within the boiler.



Water Column.



Pressure Gauge.



Steam Gauge Syphon.

Fig. 35.

GAUGE COCKS AND WATER COLUMN.

Gauge, or Try Cocks are attached to a boiler for the purpose of finding the **level** of the water. The cocks, or valves which are sometimes used, are usually three in number, and should be placed directly on the shell or head of a boiler, although they are often attached to a water column, which practice is entirely safe. A water column consists simply of a large pipe with its ends connected with the steam and water spaces of the boiler.

The lowest gauge cock is placed at the lowest level that the water may safely attain, and the uppermost cock at the highest level the water can be safely carried.

In Fig. 35 is shown a water column with the proper location of the gauge cocks.

Water Level.—To find the water level in the boiler open one of the cocks, and if steam issues the cock is then **above** the water level. Next, open the cock below this one, and if water issues it is **below** the water level, and hence the true water level must be between these two cocks.

Location.—In return tubular boilers, the lowest cock should be located about 3 inches above the upper row of tubes or flues. This insures that the tubes or flues will be covered with sufficient water at all times to prevent their burning. In water tube boilers, the lowest gauge cock should be attached about three inches above the fire line of the drum on same.

In all boilers having neither tubes nor flues, the location of the **fire line** determines the placing of the gauge cocks.

In the locomotive type of boilers, the lowest cock should be about 3 inches above the highest point of the crown sheet.

In a vertical boiler, the lowest cock is placed about two-thirds the distance of the shell from the fire box, this permitting about one-third of the shell for steam space.

The cocks on all types of boilers are usually placed about 3 inches apart.

In Fig. 36 is shown the Mississippi gauge cock, and the ball gauge cock, which are the two cocks most generally used.

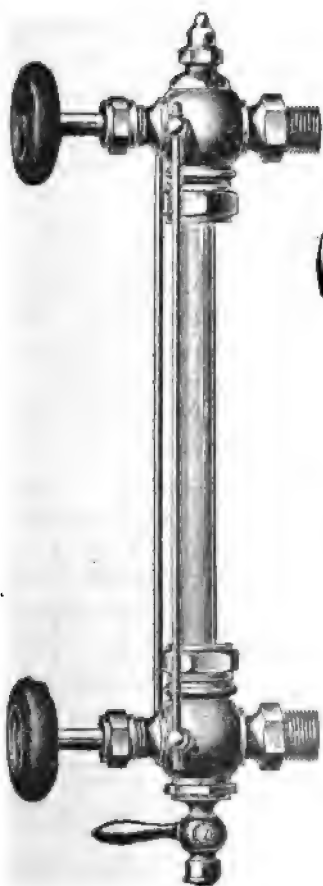
WATER OR GAUGE GLASS.

Connection.—A water glass is a glass tube with its lowest end in connection with the water space of a boiler, and its upper end connected with the steam space. Therefore, the level of the water in the gauge shows the level of the water in the boiler.

Fig. 36 shows the usual form of a water glass. The glass should be connected always directly to the head of the boiler, unless a water column is used, in which case, it is attached to it as shown in Fig. 35. It should be so located that the water will show in the middle of the glass when the water in the boiler is at its proper level.

A drip or drain cock is placed at the lower end of the glass for the purpose of draining and cleaning it.

Both gauge cocks and a water glass should be used on all boilers, so that one may be used as a check on the other. Gauge cocks are much more reliable than a water glass, as the glass not only often breaks, but it is apt to become choked with dirt and sediment from the boiler. This mud and sediment can be cleaned out by opening the drip or drain cock and allowing the steam and water to be discharged, which will blow out all such dirt and sediment.



Water Glass.



Mississippi Gauge Cock.



Ball Gauge Cock.

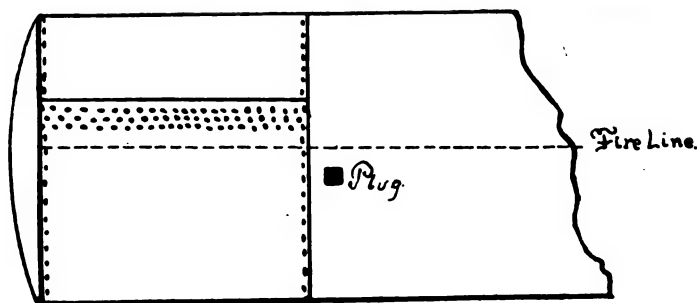
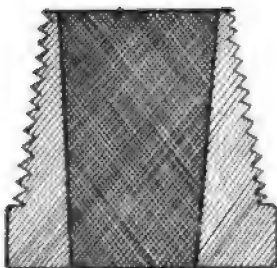
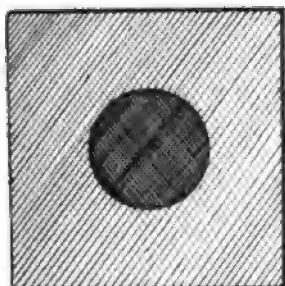
Fig. 36.

As both the safety of the boiler and the successful operation of a plant depends largely upon maintaining the water level at its proper place, therefore both the gauge cocks and water glass should be constantly tested and blown out during the day, otherwise the true water level may not be shown and disastrous results follow.

FUSIBLE PLUGS.

Use.—Fusible or safety plugs are required to be inserted in all boilers to give warning of low water. The standard form of a fusible plug is shown in Fig. 37. It consists of a brass shell threaded on the outside with a standard pipe thread. The inside cavity is filled with some alloy having a low melting point, which point is determined by the ordinary steam pressure to be carried by the boiler. This plug is inserted in the shell or drum of the boiler from the inside. In fire tube boilers, an additional plug is inserted in one of the tubes or flues. As long as the plug is covered with water, the fusible metal is kept from melting by the coolness of the water, but should the water sink below the top of the plug, the heat of the steam will melt the alloy and permit the steam to be discharged, thus giving warning of low water. The plugs are usually made with a conical filling in order to prevent the filling of alloy from being blown out by the pressure of the boiler.

Location.—In horizontal return tubular boilers, the plug is usually placed in the second sheet from the front just below the fire line, which would be about 3 inches above the upper row of tubes. One additional plug is placed in the rear end of one of the tubes. In flue boilers, one plug is inserted in a flue at its highest point.



Fusible Plug and Location in Shell of Boiler.
Fig. 37.

or in the shell or back head of boiler about three inches above the top of the flues.

In water tube boilers, it is inserted in the shell of the steam drum. In locomotive boilers, it is inserted in the highest point of the crown sheet. In vertical boilers, it should **not** be located in the crown sheet of same as is frequently done, but should be inserted in one of the tubes, about 2 inches below the lowest gauge cock.

Modern practice requires that safety plugs should be properly inserted in all boilers before they are installed. In many places this is required by law. The following is the ordinance enforced by the City of St. Louis:

St. Louis Ordinance.—All boilers shall have inserted in them plugs of brass filled with Banca tin, as follows: All cylinder boilers with flues shall have one plug inserted in one flue of each boiler; and also one plug in the shell of each boiler, as follows: All plugs in shells shall have an external diameter of not less than that of one-inch gas pipe screw tap, and an internal opening not less than one-half inch in smallest opening, all plugs to be inserted in shell from inside, on second sheet from forward end, one inch above flues; all plugs to be inserted in flues not more than three feet from after end; all plugs to be inserted in flues to have an external diameter of that of a three-fourth gas pipe screw tap, and an internal opening of one-half inch, except flues or tubes of six inches or less, when plugs may be used with an external diameter of that of three-eighths gas pipe screw tap, with an internal opening of one-fourth of an inch. The Inspector of Boilers and Elevators shall have power to have one plug placed in each boiler not provided for

in this section, as he may deem necessary for the safety of lives and property, and it shall be the duty of the Inspector to see that such plugs are filled with Banca tin at each inspection.

Care of Plugs.—These safety plugs should be removed at least once or twice a year and examined to see that the filling is not covered by scale or sediment. Unless this is done an incrustation is likely to form, covering the plug and preventing the heat of the steam from coming in contact with the filling or alloy, thus rendering the plug not only worthless, but a source of danger from its deception.

Convenient Piping for Fusible Plug.—In Fig. 38 is shown a convenient way of inserting a fusible plug in a boiler, it being not only very convenient, but sufficiently safe to pass the requirements of the law.

Construction.—Drill and tap a $1\frac{1}{4}$ -inch opening in the top of the shell or drum of the boiler, through which insert a 1-inch pipe, so that it will reach to within about three or four inches of the bottom of the drum. This pipe should be extended about 14 inches outside of the boiler, using a nipple for this purpose. At the end of this nipple place the fusible plug, inserting a valve between it and the shell of the boiler, as shown in the cut.

So long as the end of the pipe in the boiler is covered by the **water** the plug will not melt, but upon the water getting sufficiently low to permit the **steam** to enter the pipe, it melts the plug and sounds an alarm. The valve can then be closed and a new plug inserted, without the necessity of shutting down the boiler, as would have been required had the plug been inserted in the usual way in the shell.

Composition and Melting Points of Fusible Plugs.

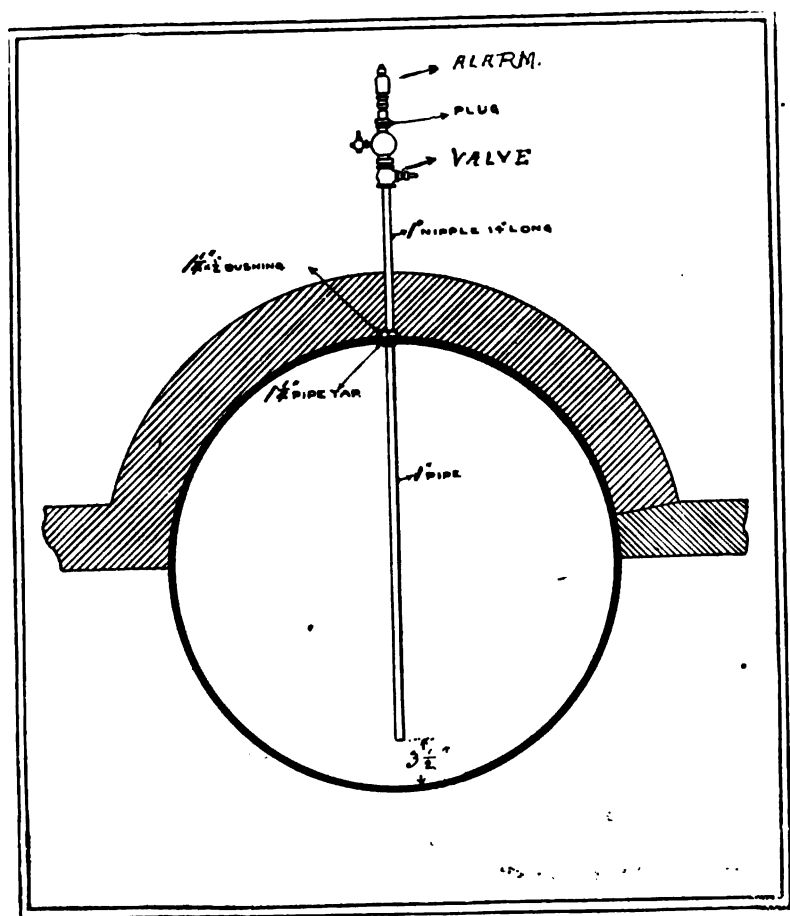
Tin.	Lead.	Melts Fahr.	Tin.	Lead.	Bismuth.	Melts Fahr.
2	6	383	4	4	1	320
2	7	388	3	3	1	310
2	8	408	2	2	1	292
6	1	381	1	1	1	254
5	1	378	3	5	8	212
2	2	372	1	1	2	201
4	1	365	2	3	3	199
3	1	340				
2	1	334				
1½	1	320				

Danger in Safety Devices.—No mention is here made of high and low water alarms which are also safety devices, and the use of which is now generally advocated. While it is true that the above safety devices are almost essential to the safe and economical operation of all boilers, their use has its disadvantages and dangers, in that it leads engineers and firemen to rely too much upon such devices, and not enough upon their own vigilance and knowledge.

HORSE POWER OF BOILERS.

Definition.—The term horse power when used in connection with boilers, generally refers to the evaporative power of the boiler, that is, the amount of steam that a boiler generates in a definite period of time, usually in an hour.

Boiler Capacity.—The capacity of a boiler for generating steam depends upon the extent and disposition of the heating surfaces, the area of the grate, and the weight of fuel consumed. The circulation of the water in the



Convenient Piping for Fusible Plug.
Fig. 38.

**APPROXIMATE WEIGHT OF ONE CORD OF DIFFERENT KINDS OF KILN-DRIED WOODS, AND
THEIR EVAPORATIVE POWER COMPARED WITH COAL OF AVERAGE QUALITY.**

KIND OF WOOD	Approximate Weight of One Cord of the Wood	Weight of Coal that One Cord of Wood is Approximately Equivalent to in Evaporative-Power
English oak	8,850 lbs.	1,560 lbs.
Ash, beech and thorn, each	8,520 "	1,420 "
Red oak, hard maple and walnut, each	8,310 "	1,340 "
Apple tree, pear-tree, cherry-tree and plum-tree, each	8,140 "	1,260 "
Birch, elm, plane-tree and hazel, each	7,880 "	1,190 "
Chestnut, brushwood and yellow pine, each	7,520 "	1,060 "
Birch pine, alder, aspen and poplar, each	7,130 "	1,070 "
Willow, white pine or deal, each	1,920 "	970 "
Hemlock	1,220 "	580 "

Table No. 2.

About 126 gallons of the crude oil is equal to one short ton of good steam coal.

In Table No. 2 is given the approximate weight of one cord of different kinds of kiln-dried woods, and their evaporative power compared with coal of average quality.

In Table No. 3 is given the comparative cost of oil and coal, together with the equivalent price of oil per barrel.

Natural Gas.—The use of natural gas as a fuel is also rapidly increasing, due to the many new wells being found in different portions of the country.

On an average, 30,000 cubic feet of this gas is the equivalent of one ton of good steam coal. Practically one pound of gas is equal to two pounds of coal.

If one ton of coal costs \$2.00, then natural gas must be worth from seven and one-half to ten cents per 1,000 cubic feet to permit of its economical use.

It is with coal as a steam producing power that we are mostly interested. In order to obtain the proper combustion of any fuel, a certain amount of air is necessary to be introduced into the furnace.

Draft.—There are several methods of producing the air required by a furnace for the combustion of the fuel, the two principal ways of producing a draft as it is called, being, viz.:

First, by means of a chimney, which is a natural draft.

Second, by means of a fan, blower or jet, which is called an artificial or mechanical draft.

Natural Draft.—Such a draft is produced by the difference between the weight of a column of hot gases contained within a chimney, and the weight of the same bulk of cold air on the outside of the chimney. It is well

COMPARATIVE COSTS OF OIL AND COAL

1. Weight of oil per gal. = 7.66 pounds. 2. These figures are net evaporation after allowing for steam consumed to produce the forced draft necessary for burning the fuel. 3. By "wet coal" is meant coal containing 3% of water	Best Semi-Bituminous, Atlantic Ocean Traffic and Mills of Eastern and Middle States									
	Small Sizes of Anthracite				Pittsburg Bituminous, Used in Mills of Pennsylvania and Ohio			Hand Fired		
	Culm	No. 3, Buckwheat or Barley	No. 2, Buckwheat	No. 1, Buckwheat and Tea				Ash 10% Ash 5% Over Fire		
1	2	3	4	5	6	7	8	9	10	
1. Pounds evaporation per lb. of wet, coal from and at 212 degrees, at about 10 square feet of heating surface per boiler horse-power	7.5	7.75 _a	8.25 _a	8.50 _a	8.75	9.50	10.00	10.50	11.00	
2. Pounds evaporation per lb. of Beaumont oil from and at 212 deg. at about 10 square feet of heating surface per boiler horse-power	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	
3. Ratio of evaporation of oil to coal — line 2 — line 1 — R	1.97	1.91	1.79	1.74	1.69	1.56	1.48	1.41	1.35	
4. Number of barrels of oil equivalent to a 2240 pound ton of wet coal — 2240 ÷ (322R) — N	3.54	3.64	3.96	4.00	4.12	4.46	4.70	4.94	5.15	

EQUIVALENT PRICE OF OIL PER BARREL OF 42 U. S. GALLONS = Pc + N = Po

	\$1.00 . . .	\$0.29	\$0.28	\$0.26	\$0.25	\$0.25	\$0.23	\$0.21	\$0.20	\$0.19
5	1.50 . . .	0.43	0.41	0.39	0.38	0.36	0.34	0.32	0.30	0.29
6	2.00 . . .	0.56	0.55	0.51	0.50	0.49	0.45	0.43	0.40	0.39
7	2.50 . . .	0.71	0.69	0.64	0.62	0.60	0.56	0.53	0.50	0.49
8	3.00 . . .	0.85	0.82	0.77	0.75	0.73	0.67	0.64	0.60	0.58
9	3.50 . . .	0.99	0.96	0.90	0.87	0.85	0.78	0.75	0.71	0.68
10	4.00 . . .	1.13	1.10	1.02	1.00	0.97	0.90	0.85	0.81	0.77
11	4.50 . . .	1.28	1.23	1.16	1.13	1.09	1.01	0.96	0.91	0.87
12										

Table No. 3.

known that any gas when heated is lighter than when cool. Now, when the hot gases pass into the chimney they have a temperature of at least 400 degrees and sometimes much higher, while the air **outside** the chimney has a temperature from 40 degrees to 100 degrees, depending upon the weather. Roughly speaking the air outside the chimney weighs twice as much, bulk for bulk, as the hot gases within the chimney. Therefore the pressure in the chimney is **less** than the pressure on the outside of the chimney, and the heavier air will flow to the place of lower pressure, that is, into the chimney through the **furnace**, it being the only inlet to same, thus producing a draft.

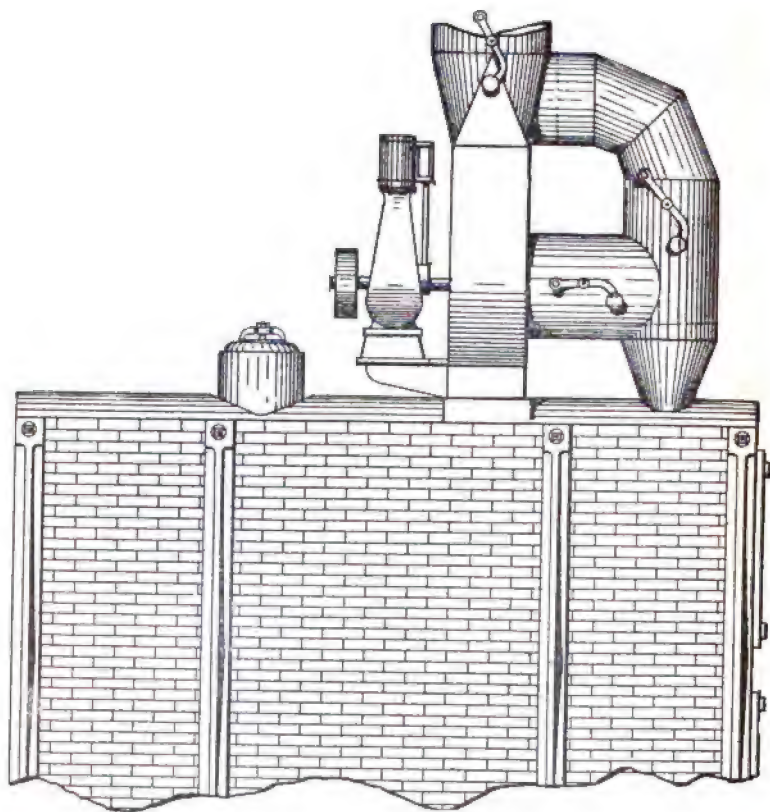
Artificial or Mechanical Draft.—This character of draft is produced by means of fan blowers or steam jets. According to the manner in which it is applied, this draft is known as a **forced draft** or an **induced draft**. Combustion is greatly increased by forcing or drawing **more air** into the furnace by these means.

Advantages.—The principal advantages claimed for mechanical draft are as follows:

- (1) The ability to control the rate of combustion.
- (2) A close regulation of the air required for combustion, thus avoiding improper combustion.
- (3) Reduction of the first cost for producing the draft required.
- (4) Permits the installation of regenerators and economizers without the necessity of providing additional means for maintaining the draft.
- (5) Permits an absolutely uniform draft, regardless of atmospheric conditions.
- (6) For increasing the draft where insufficient chimney capacity exists.



Forced Draft System.
Fig. 39.



Induced Draft.
Fig. 40.

(7) Permits the use of highly-heated air for combustion without increasing the waste heat.

(8) With mechanical draft the draft is independent of the condition of the fire, and consequently a banked fire can be started up quickly. With a natural draft, the intensity of the draft depends on the intensity of the fire, and is therefore least when the fire is low and draft is most needed.

With a mechanical draft the temperature of the furnace is always under control, and without waste of heat. Such a draft is both **positive** and **flexible**, and with it can be obtained and maintained almost perfect combustion, which means that all useful heat is utilized, and the complete absence of all smoke and smell.

With the forced draft system the air is forced through the fires from the closed ash pit, while with an induced draft, it is **drawn** through the fires by creating a vacuum over the fires. In the induced system the exhaust fan is used in place of the chimney, or supplementary to it, the products of combustion being drawn into the fan and exhausted into the chimney, which needs to be merely high enough to carry the smoke and gases clear of the roof of the building. The fan itself maintains the partial vacuum that would exist with a chimney of suitable height. Figs. 39 and 40 show these two systems in operation.

With the induced draft system the maximum intensity of the draft obtainable is greater and permits a much wider range regulation than with the forced-draft system. The leakage of air is also inward, thus avoiding the constant outward leakage, as in the forced-draft system.

The induced-draft system offers the additional advantage that the supply of air above the fire can be nicely

adjusted to secure more perfect combustion. While the maximum intensity of the draft of the chimney is largely dependent upon atmospheric conditions, as well as height, the intensity of the draft when produced mechanically is limited only by the speed of the fan, which can be made to cover a wide range of conditions.

When a forced draft alone is used with a chimney, the forced draft and the chimney pull should be so regulated that a **perfect balance** of the gases is maintained. When such a condition exists no cold air can be drawn into the furnace, even when the fire doors are left open.

Perfect Combustion.—In order to produce combustion, the carbon and hydrogen in the coal must combine with the oxygen in the air, and when we get the **proper** combination of these elements the result is **perfect combustion**. A high furnace efficiency demands a proper amount of air be supplied to the furnace per pounds of fuel burned. If **too little** air is supplied, it results in loss due to the incomplete combustion of the fuel, part of the carbon being burned only to carbon monoxide CO instead of to carbonic oxide CO_2 , as it should be if the combustion is complete. On the contrary, **too much** air lowers the temperature of the furnace gases and thereby decreases the heat transferred per unit of heating surface, owing to the slight difference between the heated gases of the furnace and the temperature of the water inside the boiler. Too much air also **accelerates** the flow of gases through the tubes and flues of the boiler, thus giving less time for their heat to be absorbed. It is therefore necessary that only the amount of air required to burn the coal be admitted to the furnace. The amount varies, but it is generally found that from 12 to 24 pounds of air is needed to burn one pound of coal.

In order that one may clearly see why this amount of air is necessary for the proper combustion of coal, it is known that the air is composed of 21 parts of oxygen and 79 parts of nitrogen by volume, or 23 parts of oxygen and 77 parts of nitrogen by weight; and when we remember that the air that supplies a boiler furnace, or any other furnace, is supplied by **volume**, or according to the **space** vacated by the products of combustion, we see that it is necessary to take in a great deal of **air** containing an element that we do not need, in order to get the **oxygen** which is necessary for combustion.

Draft Water Gauge.—The intensity of the draft is measured by means of a water gauge, as shown in Fig. 41. The gauge consists of a glass tube, open at both ends, bent to the shape of the letter U. To use the gauge the left leg is connected with the chimney and the right leg left open to the outside air. The air outside the chimney being heavier, it presses on the surface of the water in this leg, and forces some of it up higher in the left leg. The difference in the two water levels in the legs represents the intensity of the draft, which is expressed not in ounces, but in inches.

Amount.—Wood requires one-half inch of draft; bituminous coal requires less draft than anthracite. To burn **anthracite** or slack coal requires about one and one-fourth inches of draft. Two inches is about as much draft as can be obtained with a natural draft, but with a mechanical draft five inches, if necessary, can be easily obtained; the rate at which it is necessary to run the fan depending upon the temperature of the heated gases.

Test.—The standard test for determining the efficiency of combustion is the test for CO_2 (Carbonic oxide). The more perfect the combustion, the **higher** being the percentage of this gas. With 2 per cent only of

CO₂ in the gases of combustion, the loss of heat would be as high as 60 per cent, due to the heat being absorbed by the excessive amount of cold air admitted to the furnace. With 10 per cent of CO₂, the loss of heat is reduced to 15 per cent, while with 15 per cent of CO₂, the loss becomes only about 10 per cent.

On the contrary, the greater the per cent of CO (carbon monoxide), the more **imperfect** the combustion, due to the lack of sufficient air.

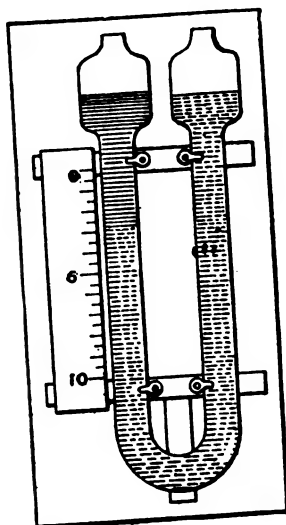
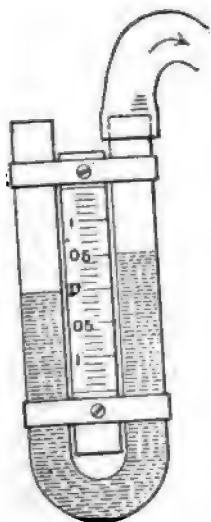
Smoke.—As we have before stated one of the most serious problems that confronts the engineer or fireman is the prevention of smoke which forms from the imperfect combustion of "soft," or bituminous, coal.

Smoke consists of the minute particles of solid carbon left when the hydro-carbons are but partially burned. **Smoke therefore indicates imperfect combustion.**

Smoke Prevention.—In order to prevent smoke we must have complete combustion, and in order to obtain complete combustion, we must maintain a **high temperature** in a properly designed furnace, with ample space for the gases. In an externally fired boiler, this is obtained by making the space above the fire sufficient to allow the gases to become completely consumed. The average distance between the grate bars and the crown sheet is therefore usually made about 2 feet.

If this distance is made too great, some of the effect of the heat is lost; if the distance is too small, the plates are likely to be damaged by being burned, and the combustion is also impaired. In internally fired boilers this presents one of the chief troubles, the combustion and radiating spaces being often sacrificed for a large grate area.

Smoke is produced not so much from improperly constructed furnaces, as from the improper operation



Draft Gauges.
Fig. 41.

Q. Can you give an example of this?

A. Yes, one pound of coal has an average evaporative capacity of 14.69 pounds of water, or, one pound of peat, if all the heat is utilized, will evaporate 7.41 pounds of water.

Q. How can one obtain the different values of fuels?

A. From tables of evaporation, such as given in Table No. 12.

CHAPTER IV.

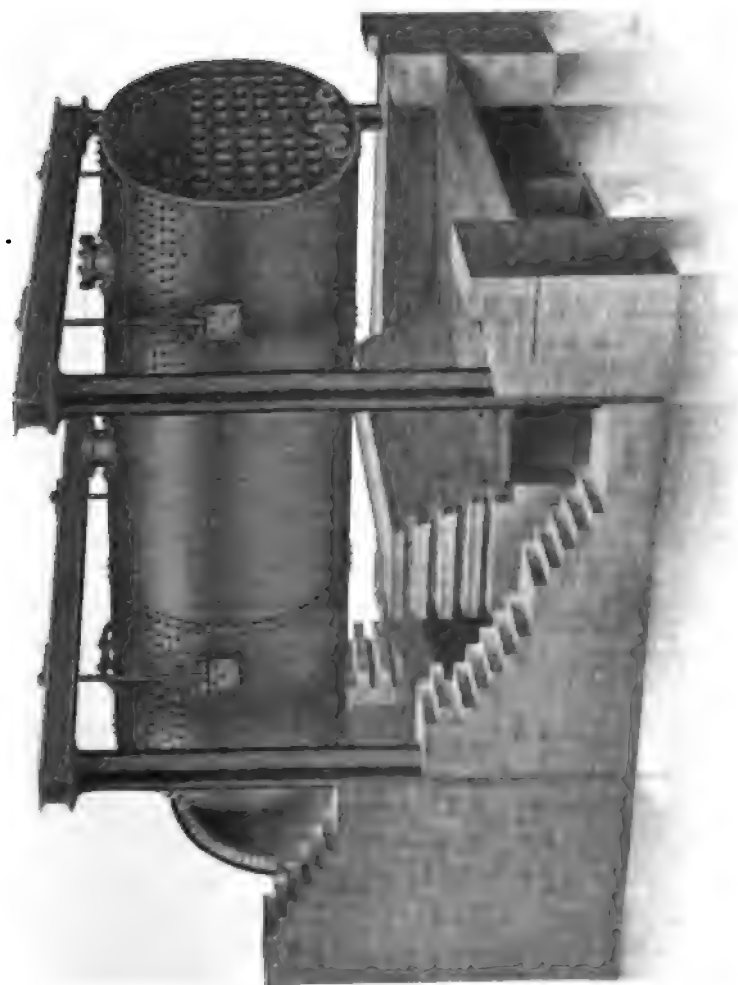
BOILER INSTALLATION.

Boiler Setting.—In boiler setting there are three things necessary for both safety and economy in the operation of boilers, viz.: (1) a firm support for the boiler shell; (2) properly arranged space for furnace and ash pit; (3) a protective covering that will prevent the loss of heat by radiation from the boiler as far as possible.

Supporting Boilers.—There are two principal methods for supporting boilers, viz.: by **brackets** riveted to the shell plates, and by supporting them from overhead girders by means of hooks, rings, etc.

Externally Fired Boilers.—Such boilers are usually supported by cast iron lugs riveted to the shell and resting on the side wall, or they may be suspended from overhead girders by means of hooks or rings. In supporting boilers with long shells, it is necessary to arrange so that each support will bear its proper proportion of the load and at the same time allow the boiler to expand freely under all changes of temperature.

Fig. 46 shows a horizontal tubular boiler with suspension settings. Such setting consists of two girders, each made from two steel I beams, the whole resting on four extra heavy cast iron columns of a certain construction. The cast iron columns are preferred to those of steel, as the steel are more apt to warp and spring. The principal advantage in the suspension setting, is that from time to time as it becomes necessary to tear down the brick walls, or to reset the fire brick, the boiler, being absolutely independent of the brick work, is not disturbed and needs no blocking.



Horizontal Tubular Boiler with Suspension Settings.

Fig. 46.

Fig. 47 and 48 show the correct settings of horizontal tubular boilers, while the standard measurements for settings is shown in accompanying table of measurements, being Table No. 7.

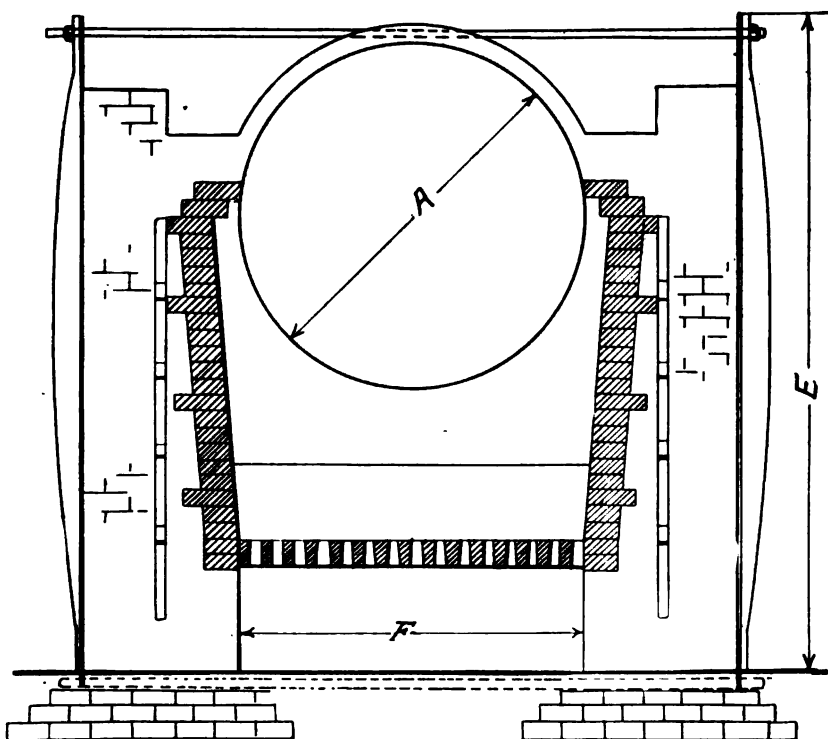
Fig. 43 shows the complete settings of a horizontal tubular boiler with a **down draft furnace**.

In Fig. 47 is shown the ordinary settings for horizontal boilers.

The foundation is heavy stone work laid to a depth of 3 or 4 feet below the surface. On top of this is laid the brick work. The side and rear walls are double, with a 2-inch air space between the inner and outer parts. The inside wall next to the furnace is faced with fire brick, as is also the bridge wall and all portions in direct contact with the flames or heated gases.

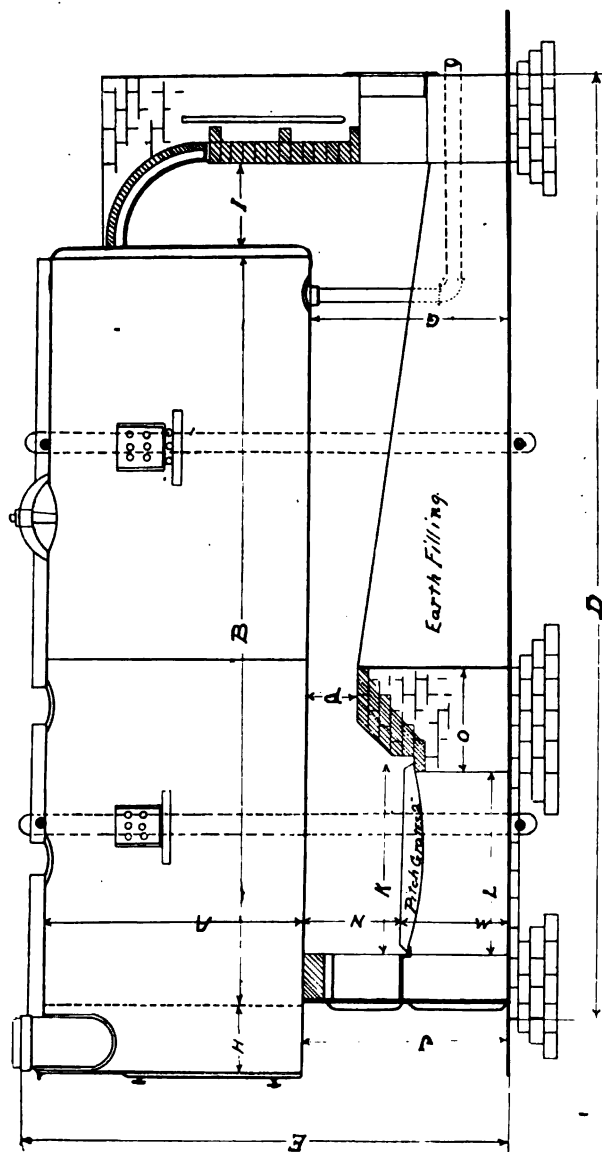
The boiler is supported by cast iron lugs riveted to the sides of the shell. These lugs rest on iron plates placed on top of the side wall. The front lugs rest directly on the plates, but the back lugs rest on **rollers** of 1-inch round iron. This permits a free expansion and contraction of the boiler. The rear wall is usually 24 inches from the rear head of the boiler, so as to allow sufficient space for the hot gases to enter the tubes. Above the tubes this wall is built in to meet the head and forms a roof for this combustion chamber. In order to remove the dirt and soot that collects mostly at this point and also to provide means of inspection, there is a door placed in the rear wall.

The fire grates are placed about 24 inches below the shell, though this distance varies with the character of fuel to be burned. For the burning of bituminous coal, the distance between the grates and the shell should be from 30 to 36 inches. The grates should have a fall of 3 inches from front to the rear, which makes it easier



Settings with Dimensions for Horizontal Tubular Boilers.
 Letters Refer to Table of Setting Plan.

Fig. 47.



Settings with Dimensions for Horizontal Tubular Boilers.
 Letters Refer to Table of Setting Plan.
 Fig. 48.

to clean the fire from below and at the same time facilitates the admission of air to the rear of the furnace.

The brick work of the side walls is closed in with the shell at the level of the upper row of tubes in order to prevent the heated gases coming in contact with the shell above the water line. It is most important that the water line of all boilers be **above** the fire line. No part of the shell should ever be exposed to fire or heated gases of combustion which is not completely covered with water. The fire line of a boiler determines the water line. In boilers without tubes or flues, or with steam drums as on water tube boilers, the fire line is determined by the closing in of the side walls, and the water line is determined by the fire line.

The brick work of the setting of boilers must be strengthened by **buck staves** held together by tie-rods, as shown in Fig. 47. The buck staves should be made of wrought iron channel or angle irons.

Suspension of Tubular Boilers.—Fig. 49 illustrates a plan of suspending tubular boilers which sometimes recommends itself. The upright posts are cast iron—the horizontal beams are made of two steel channels, back to back, bolted together, with separators between. The suspension bolts are round, with nuts and washers at the top, allowing the taking up of any settling of foundation. The brickwork around boiler can be entirely removed without disturbing boilers or connections. The usual lugs on boilers are replaced with forged loops, as shown.

The brick walls should never be built solid, but always with an **air space** left in them of at least 2 inches in width in order to prevent the conduction of heat to the outer walls, as air is a non-conductor of heat. This air space is shown in Fig. 50 of Double Boiler Settings.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
48	14'-0"	7'-11"	18'-0"	8'-0"	43	45	14 $\frac{1}{2}$	18"	46 $\frac{1}{2}$	54	51	22 $\frac{1}{2}$	24	24	10
48	16'-0"	7'-11"	20'-0"	8'-0"	43	45	14 $\frac{1}{2}$	18"	46 $\frac{1}{2}$	54	51	22 $\frac{1}{2}$	24	24	10
54	14'-0"	8'-5"	18'-2"	9'-0"	49	46 $\frac{1}{2}$	16 $\frac{1}{2}$	20"	48 $\frac{1}{2}$	48	45	24 $\frac{1}{2}$	24	24	12
54	16'-0"	8'-5"	20'-2"	9'-0"	49	46 $\frac{1}{2}$	16 $\frac{1}{2}$	20"	48 $\frac{1}{2}$	54	51	24 $\frac{1}{2}$	24	24	12
60	14'-0"	8'-11"	18'-2"	9'-6"	55	46 $\frac{1}{2}$	16 $\frac{1}{2}$	20"	48 $\frac{1}{2}$	54	51	24 $\frac{1}{2}$	24	26	12
60	16'-0"	8'-11"	20'-2"	9'-6"	55	46 $\frac{1}{2}$	16 $\frac{1}{2}$	20"	48 $\frac{1}{2}$	54	51	24 $\frac{1}{2}$	24	26	12
60	18'-0"	8'-11"	22'-2"	9'-6"	55	46 $\frac{1}{2}$	16 $\frac{1}{2}$	20"	48 $\frac{1}{2}$	60	57	24 $\frac{1}{2}$	24	26	12
66	16'-0"	9'-5"	20'-4"	10'-6"	61	48 $\frac{1}{2}$	17 $\frac{1}{2}$	22"	50 $\frac{1}{2}$	54	51	24 $\frac{1}{2}$	26	26	12
66	18'-0"	9'-5"	22'-4"	10'-6"	61	48 $\frac{1}{2}$	17 $\frac{1}{2}$	22"	50 $\frac{1}{2}$	60	57	24 $\frac{1}{2}$	26	26	12
72	16'-0"	9'-11"	20'-6"	11'-0"	67	48 $\frac{1}{2}$	19 $\frac{1}{2}$	24"	50 $\frac{1}{2}$	60	57	24 $\frac{1}{2}$	26	30	12
72	18'-0"	9'-11"	22'-6"	11'-0"	67	48 $\frac{1}{2}$	19 $\frac{1}{2}$	24"	50 $\frac{1}{2}$	66	63	24 $\frac{1}{2}$	26	30	12

Table of Measurements for Settings of Horizontal Tubular Boilers.

Letters Refer to Setting Plans, Fig. 47 and Fig. 48.

Table No. 7.

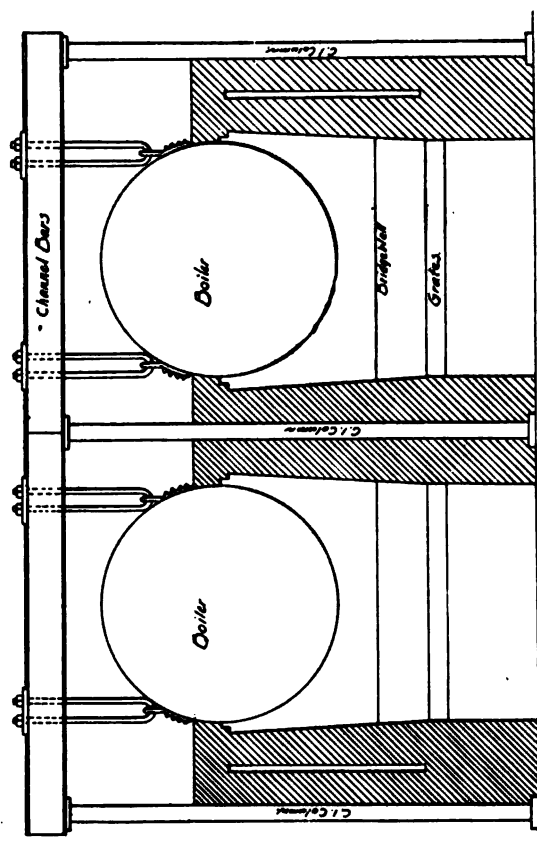
Self Contained Boilers.—Vertical and locomotive type of boilers, and practically all internal fired boilers, are self contained and require no setting. The vertical tubular boiler rests on a cast iron base which forms the ash pit. Locomotive, or portable boilers as they are called when used for stationary work, are supported on cast iron saddles and skids, as shown in Fig. 10.

Settings of Water Tube Boilers.—The settings for water tube boilers are essentially similar to the settings of horizontal tubular boilers. The settings for these boilers vary only in the baffling of the gases, and the tiling required to conduct the gases in such a way as to keep them in contact with the tubes. Fig. 52 shows a water tube boiler installed, with measurements and proper settings for same. Fig. 53 shows the ordinary type of a water tube boiler in course of erection, while Fig. 54 shows the Sterling water tube boiler in course of erection.

Boiler Fronts.—Boiler fronts are made in many different styles, the four principal styles or designs being;

- (1) The flush or full-arch front, as shown in Fig. 55.
- (2) The over-hanging or half-arch front, as shown in Fig. 56.
- (3) The cut-away front, as shown in Fig. 57.
- (4) Fronts with breeching.

The Flush or Full-Arch Front.—This is the most generally used style, and gives good satisfaction so long as the furnace walls are in proper repair. But at any time should the brick fall away from over the fire door, it will leave exposed to the heat, portions of the dry sheet causing it to be burned or otherwise injured by the heat, and probably starting a leak around the front row of rivets. A common form of this front is shown in Fig. 55.



Suspension of Tubular Boilers.

Fig. 49.

Over Hanging or Half-Arch Front.—In this style of front the above objection to the full-arch front is entirely avoided, as the dry sheet projects out into the boiler room and is not exposed to the furnace heat. Should the fire brick fall away, no damage can be done since the sheet which would then come in contact with the heat is entirely protected by water on the inside.

This front setting has a further advantage that it occupies less floor space than the full-arch, and hence will require also a smaller number of common brick and fire brick.

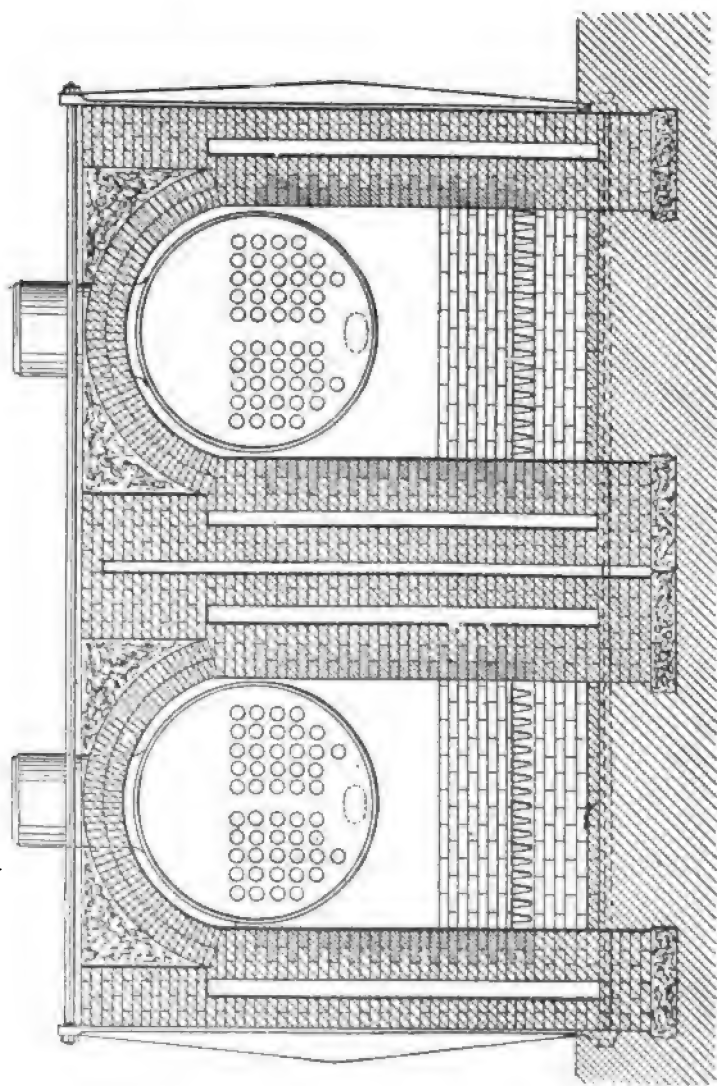
The **disadvantages** of this front setting is that the projecting smoke-box interferes to some extent with the work of the fireman. A common form of this front is shown in Fig. 56.

The Cut-Away Front.—To meet the objection to the projecting half-arched front, the cut-away style has come into use. In this front setting the lower portion, or the front sheet, is cut obliquely away, so that at the lowest point the boiler projects but little beyond the brick work, and hence cannot interfere with the firing of the furnace. A common form of this front is shown in Fig 57.

In addition to these styles of boiler front settings there are many fronts of highly ornamental design, but they can all be included under one of the above four styles.

In Fig. 58 is shown the usual style of front setting used for **water tube boilers**.

Material.—Two kinds of brick are used in boiler settings—the **common red brick** for the supporting walls and backing to the furnace, and **fire brick** for the lining of the furnace and for all points where the fire or hot gases come in direct contact with the furnace or flues.



Cross Section of Double Boiler Setting, Showing Air Space.

Fig. 50.

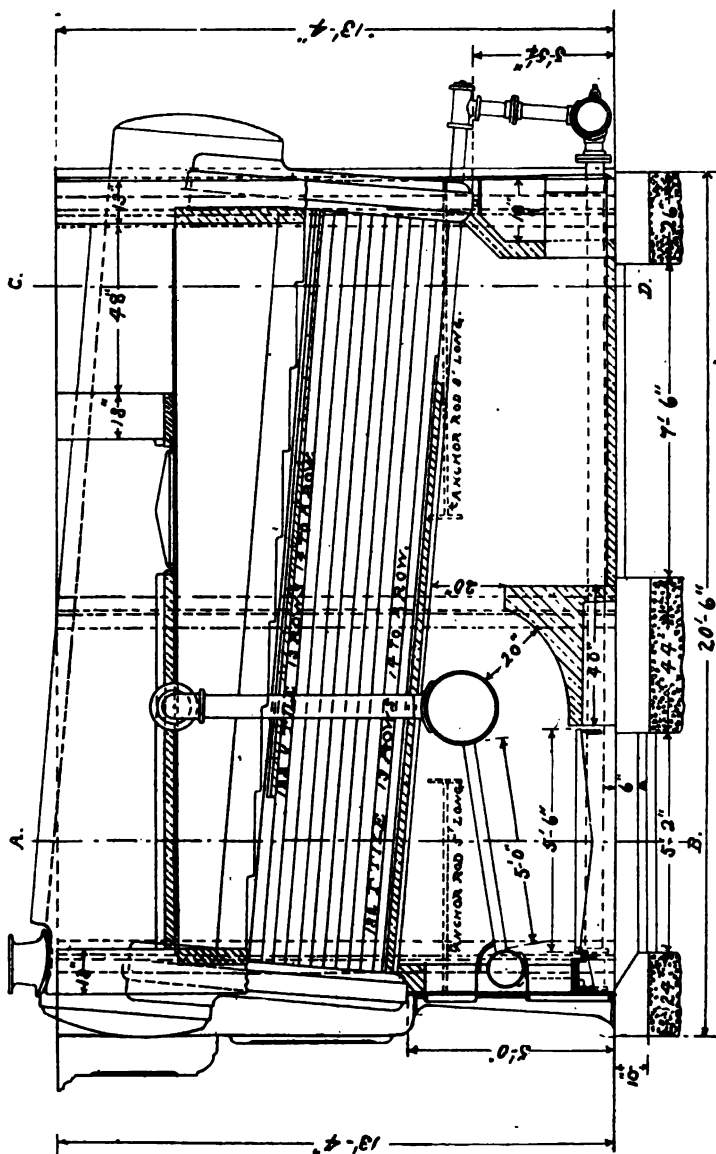
Usually 9 inches of fire brick lining is used in the furnace, and $4\frac{1}{2}$ inches behind the bridge wall. The common fire brick used for furnace work are $9 \times 4\frac{1}{2} \times 2\frac{1}{2}$ inches in size. The advantages that fire brick possess over the common red brick are, their power to resist for a long time the highest temperature without fusion, and of being capable of resisting sudden changes of temperature without injury.

• **Fire Clay** is used instead of ordinary mortar to cement the fire brick together, as mortar will not stand the intense heat.

Requirements of Boiler Settings.—A high furnace heat with as little waste as possible is the chief requirements for both furnace construction and boiler setting. To obtain this there must be, (1) a sufficient thickness of the walls to **retain** as far as possible every unit of heat. (2) The furnace construction must provide for a proper **mixture** of the air drawn into the furnace. (3) There must be a proper **proportion** of grate and heating surface. (4) Also, a correct proportion between the grate surface, and the **total area** of the tubes and the height an area of the chimney.

Location of Boilers.—Next in importance to the **safety** of the boiler is its proper location in the plant, as on this to a large extent depends the **economy** of the plant. While no fixed rule can be laid down for the location of the boiler or boilers, as this will depend largely upon their character and the work required of them, there are certain things which must be always **avoided** irrespective of the character of the boiler or the work required of it.

No wall of the building should ever form a wall for the boiler setting, as the heat from the boiler furnace will cause unequal expansion and contraction between it



Longitudinal Section of a Water Tube Boiler, Showing Settings with Measurements. Fig. 52.

and the other supports of the boiler, causing the wall soon to crack and become unsafe.

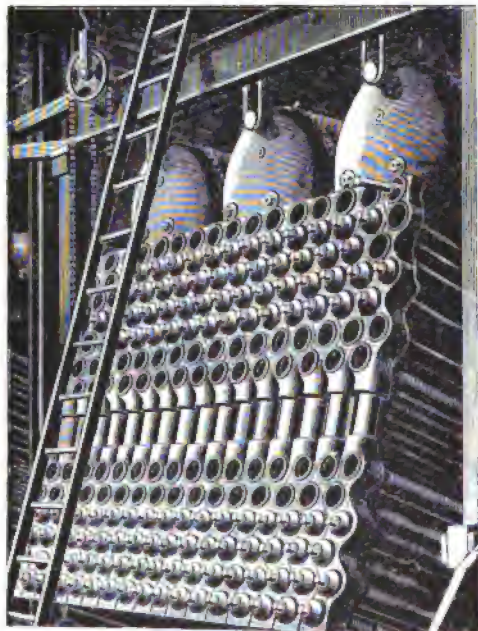
The boiler room should be made of ample height and dimensions, and on a level with the engine room, which room should be separated from it by a brick partition. There should be as little distance as possible between the boiler and the engine in order to avoid the waste from condensation as much as possible; and all parts of the boiler and engine room should be easy of access and so arranged as to be at all times within full view of the engineer. There should be sufficient ventilation provided both for the health and comfort of the attendants.

The blow-off valves should never be placed outside of the building, but either boxed in or packed with some non-combustible material where they can always be accessible to inspection, as should be all valves and attachments to the boiler.

All valves should be kept carefully packed to prevent leaking, as permitting the valves to leak not only ruins the valve in a short time but causes a large waste of fuel.

Installation.—The installation of a complete boiler plant includes the setting of the boiler or boilers, and the location and arrangement of the various accessories of same; such as feed water heaters, purifiers, separators, feed pumps, injectors, etc., and should the plant be large and more elaborate, the installation would then also include the installing of economizers, mechanical stokers, coal conveyors, etc.

A small plant, though, often consists only of one boiler and a boiler feed pump, but the stationary engineer should be prepared to install and operate any char-



A Water Tube Boiler in Course of Erection.

Fig. 53.

acter of plant, irrespective of its size, that he may be called upon to take charge.

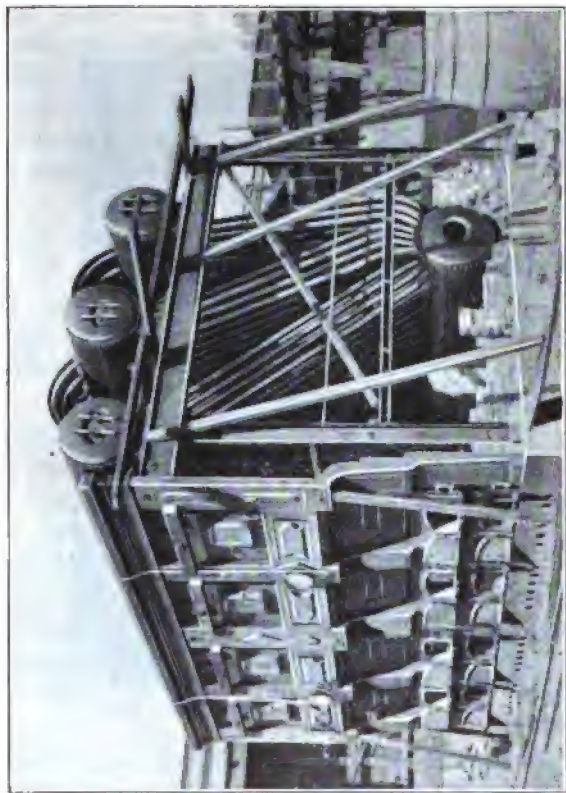
Piping.—All pipes which through accident or otherwise might cause a shut down of the plant, should be in **duplicate**. For the larger sized pipe flanged joints should be used, as such joints can be more easily and quickly handled than screwed joints. All pipes should be arranged so as to be easy of access for repairs, and should be placed **below** the floor wherever it can be done, although overhead pipe is much more accessible.

While it is not necessary that an engineer should be a good steam fitter, he should nevertheless have a good knowledge of **steam fitting**, especially of pipes and valves. The first work an engineer does on taking charge of a plant, is to ascertain the course and condition of all the water, steam, blow-off and drain pipes.

While the construction and material of pipes differ a great deal according to the work for which they are to be used, most all pipes used in a steam plant are made of **wrought iron**. Formerly cast iron pipe was almost exclusively used in steam plants, but the high steam pressure now required, has necessitated the use of stronger pipe and one that can be more easily handled. The advantages of wrought iron pipe are its lightness, its strength and the ease with which various lengths can be obtained.

Pipe manufactured from double thick iron is called extra heavy pipe, or X pipe, while pipe double the thickness of this is called XX pipe.

Size of Piping.—The size of pipes is designated by its **internal diameter**, while that of boiler tubes is designated by the external diameter.



The Sterling Water Tube Boiler in Course of Erection.
Fig. 54.

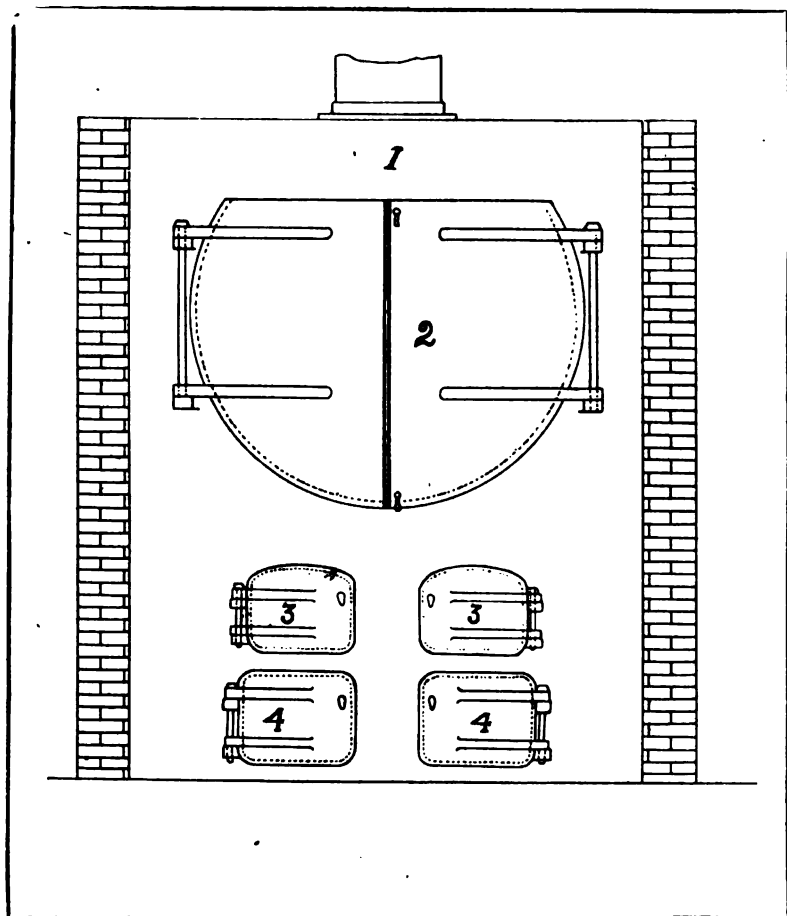
The **Table of Iron Pipe**, showing standard dimensions, being Table No. 8, gives data especially useful to all engineers and firemen.

All pipe $1\frac{1}{4}$ inch and less in diameter are made **butt welded**, while sizes $1\frac{1}{2}$ inches and larger are made **lap welded**. While but little seamless steel pipe is as yet used in a steam plant, its use is being rapidly adopted in the construction of boiler and water-grate tubes. Though it is much more **expensive** than other pipe, it is far stronger, lighter and more serviceable.

Pipe Fittings.—By pipe fittings is meant the necessary couplings and connections used in connecting up pipe. Such pipe couplings consist of flanges, unions, tees, elbows and nipples as shown in Fig. 59 of Steam Pipe Fittings.

Coupling.—In wrought iron pipe work, the general practice in making joints between pipes is a wrought iron coupling with tapered threads at both ends. Such couplings are used for the smaller sizes of pipe, while a union or a flange is used for the larger sizes. When using a coupling, the ends of the pipe are brought near together and the coupling then screwed over the ends. This requires the inside diameter of the coupling to be larger than the outside diameter of the pipe.

Union.—Where a stronger and more convenient joint is required than can be made with a coupling, a union is used. This consists of three pieces, together with the washer which is used on the larger sizes. A common form of a union is shown in Fig. 60. Unions are also made with ground-joints and the washer is then not needed, as a tight joint can then be made without it. When the pipes are above 4 or 5 inches in diameter, a **flanged union** should be used. This union consists of two circular cast iron flanges with a requisite



Flush or Full-Arch Boiler Front.

Fig. 55.

number of holes for bolts through each, and a large central hole tapped to receive the threaded ends of the pipe. The two flanges are screwed onto the ends of the pipe and then bolted together, thus making a much stronger and tighter joint than is possible with the ordinary coupling.

The adbutting faces of the flanges are generally "faced," or turned smooth, and a **gasket** placed between them to prevent leaking.

Elbow.—In order to avoid sharp angles in joining together pipe, which would cause friction in the flow of the liquid or gas through them, an elbow or ell as it is usually called, is used to make the necessary turns in the course of the piping.

A **street-elbow**, or street-ell, is an elbow threaded externally at one end so that it can be used as a connection between different size pipes.

Tee.—When a second pipe is to be joined to a line of pipe at an **angle** to it, usually a right angle, a tee or "T" as it is abbreviated, connection is used.

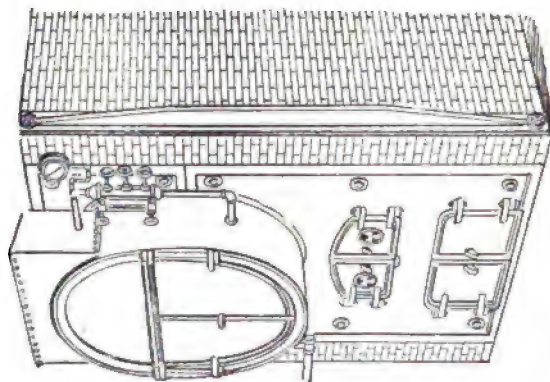
A **cross-tee** is used when **two** such pipes are to be joined to a line of piping.

Plug.—A plug is used to stop an aperture in plates or pipes.

Bushing.—A bushing is used to **reduce** one size pipe in a line to another.

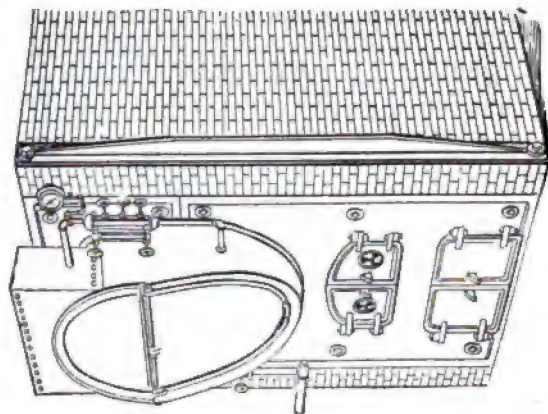
Nipple.—A nipple is simply a short piece of pipe threaded externally at each end. A **close nipple** is a short piece of pipe threaded externally its **entire** length.

Valves.—A valve is a lid to an opening so constructed that it can open or close communication in same. Among the **varieties** of valves may be classed the cock, the slide valve, the poppet valve, the pump and the clack valve.



Over-Hanging or Half-Arch Boiler Front.

Fig. 56.



Cutaway Boiler Front.

Fig. 57.

A valve always has a seat, which is simply the opening on which it rests. They are usually operated by a circular handle fitted to a spindle, by the turning of which the valve can be opened or closed.

Cock.—A cock is a conical plug slotted and fitted with a handle for turning the slots, or openings, in line with the opening of the pipe. Fig. 262 illustrates the common form of a three-way cock used in steam work. A cock is a valve, but a valve is not necessarily a cock. When the opening is closed by moving the lid or disk across the opening of the pipe with or without rotation, it is a valve. When it is opened or closed by turning through an **angle**, it is then a cock. Cocks are mostly used on the blowoff pipe of boilers; asbestos packed plug cocks being generally used for this purpose, as such packing overcomes the difficulty of moving the plug when the cock has been closed for some time.

Globe Valve.—The globe valve, a view of which is shown in Fig. 61, derives its name from the **shape** of the case or bonnet enclosing the valve. This case is divided into two parts by a partition with an opening through the horizontal part. The fluid or gas enters at the right and passes **up through** the opening and out at the left. It is closed by screwing down the valve on the opening which forms the seat. A stuffing box around the spindle or stem which is used to screw down the valve on the seat, prevents its leaking. If the disc or valve is round, it is called a disc valve. This disc may be made **removable**, so as to permit it being easily removed when worn from use so as to cause it to leak.

Globe valves must always be set so as to close **against** the flow, so that the valve could be opened should it become detached from the stem or spindle.



Ordinary Front for Water Tube Boilers.

Fig. 58.

This also permits the valve to be packed without shutting off the entire flow through the pipe, as this might necessitate the shutting down of the plant.

The **disadvantages** of the globe valve is the **resistance** or friction caused by the two turns, which are almost at right angles, necessary to be made by the liquid or gas in passing through the valve. In Fig. 62 is shown a section of a Crane Globe valve. In Fig. 63 is shown the Jenkins Globe Valve, which is a standard valve among engineers.

Gate Valve.—To overcome this objectional friction in a globe valve, the gate valve is constructed as shown in Fig. 64. In this valve by turning the stem or spindle, the wedge-shaped disc is moved vertically across the opening or orifice. The disc has cast on its lower side, a projection that rests on a corresponding projection which is cast with the valve body. These two projections form a stop for the disc and hold it tightly in place. As the disc moves vertically up and down, the valve may be put in so as to receive the pressure on **either** side. In Fig. 64 is shown in section this valve as made by the Western Tube Co.

Angle Valve.—This style of valve is used at the junction of two pipes at a right angle. Its construction otherwise is similar to the globe valve, and, like that valve it should be attached to the pipe in such a manner that the pressure from the liquid or gas will be **up** against the disc and not on it. This requires the valve to always close **against** the pressure.

Check Valve.—This valve is designed to permit the flow of liquids or gases in one direction only, and to prevent any return flow. There are several forms of check valves manufactured, the most common form being known as the **Globe Check**.



45° Elbow.



Elbow.



Tee.



Cross.



Coupling, R. H.



Bushing.

Standard Steam Pipe Fittings.
Fig. 59.

In this form, the valve is a solid disc of metal which is held to its seat by wings which are placed on the disc both above and below. The fluid or gas passes in under the disc, and raising it from its seat flows on through in the same direction. Its return is prevented by the pressure being all on top of the disc, which as seen from the construction will close the opening at once by forcing the valve on its seat.

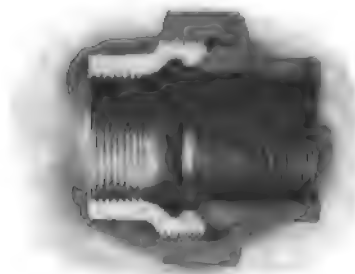
Another common form of this valve is the **swing check** as shown in Fig. 65. The valve disc is attached to an arm that swings on a pin. The passage of the fluid or gas through the valve swings open this disc. Should the flow return in the opposite direction, the pressure at once closes this disc and holds it to its seat.

These two forms of check valves are chiefly used for working in a **horizontal** position. For **vertical** work the construction of the valve is different, but its operation remains the same.

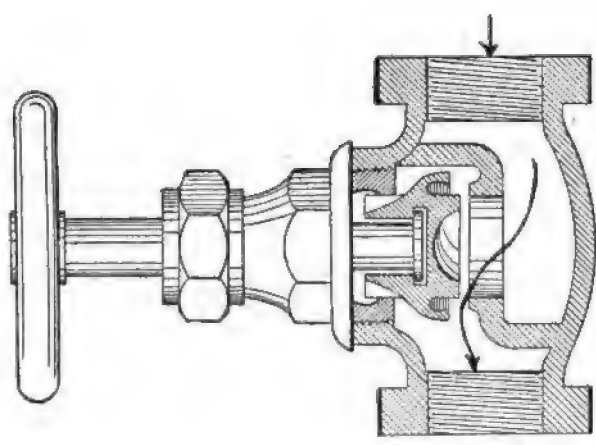
Reducing Valve.—Where steam is desired at a lower pressure than that of the boiler, a reducing valve is used. This result is accomplished by automatically throttling the steam, so as to reduce the pressure and at the same time maintain a constant pressure in the steam pipes.

There are several forms in general use. In Fig. 66 the ordinary operation of this valve is shown, in which the valve is held open by the spring and levers until the steam pressure at the exit presses on a diaphragm sufficiently to close it. Fig. 66 is a sectional view of the Davis Pressure Regulator or Reducing Valve.

The Layout of Steam Plants.—As a rule the stationary engineer is not called upon to design and superintend the installation of a steam power plant, but only to **operate** same safely and economically. But he should be able to fully understand the **layout** as well as the



A Pipe Union.
Fig. 60.



Sectional View of a Globe Valve.
Fig. 61.

operation of any plant which he may be called upon to take charge.

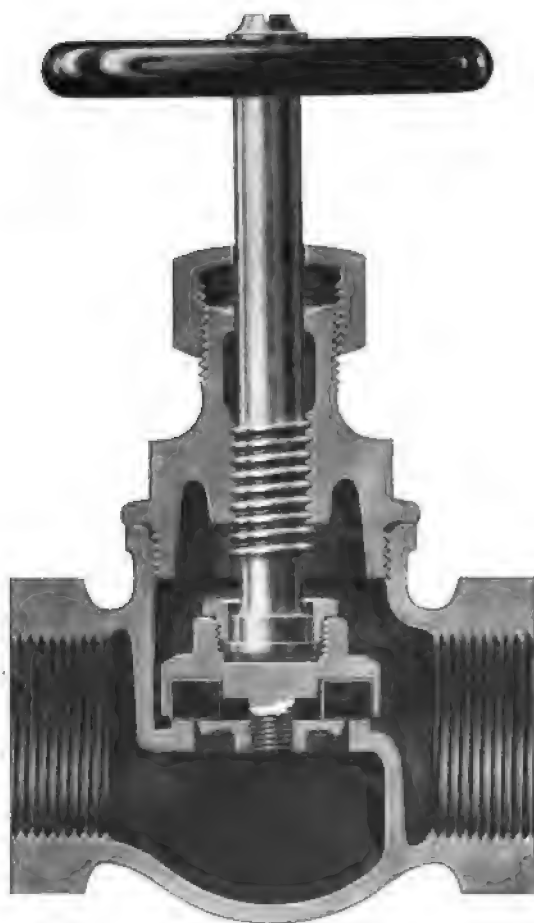
By the layout of a plant is meant its **complete design**, including every detail not alone of the boilers, engines, dynamos, etc., but of all the accessories to same, including the piping.

This work is usually done by the **consulting engineer**, the stationary engineer being only called upon to operate the plant after it is complete; but neither the consulting or stationary engineer can do justice to the owner of the plant unless **each** possess certain knowledge and experience required by the other. No consulting engineer can successfully design and install a steam power plant, unless he can **operate** the same should he be called upon to do so.

An engine, boiler, or dynamo may do the work required of it, but it may be so proportioned as to do it in a most uneconomical manner. For instance, while an engine may give the required power, its cylinders may be so small as to require an excessive amount of steam to run it; or a boiler may be so badly designed or so much too small for the steam necessary to be generated, that an **abnormal** amount of coal must be burned in order to generate the steam required.

Where a consulting engineer is not employed, it is usual for the owner of the plant to advertise for bids, and accept the lowest bid irrespective of the quality offered. No greater mistake can be made by the owner of any plant, for experience has shown that the **cheapest** machinery in the end is the most **costly**.

The chief requirement for the proper designing and construction of a plant is a good consulting engineer; and the largest return that the owner will receive from the capital invested in a plant, will be found to be in the



Section of the Crane Globe Valve.
Fig. 62.

great saving in the economical operation of the plant by a good stationary engineer.

QUESTIONS AND ANSWERS.

Q. What three things are necessary for proper boiler settings?

A. (1) A firm support for the boiler shell; (2) proper arranged space for furnace and ash pit; (3) a protective covering that will prevent the loss of heat by radiation from the boiler as far as possible.

Q. Why should a long cylindrical boiler be supported from three points?

A. Because the lower part of the shell expands more than the upper, which will cause the shell to sag in the middle.

Q. When horizontal tubular boilers are supported by lugs resting on the side walls, how is any trouble from expansion and contraction of the boiler avoided?

A. By putting **rollers** under the rear lugs, thus permitting the rear end of the boiler to move horizontally.

Q. How much of the boiler should **never** be exposed to the fire or heated gases?

A. No part of the shell or tubes not completely covered with water.

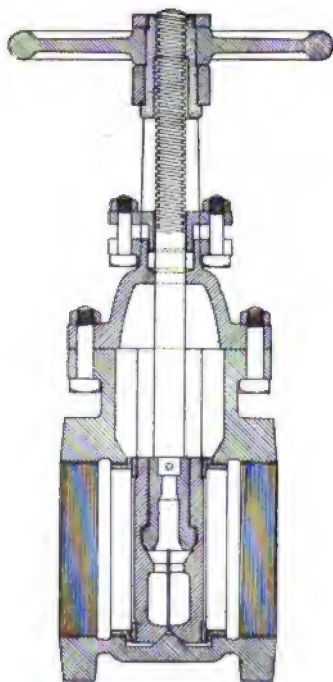
Q. What is the object of laying the fire brick of a boiler with rows of **headers** at short intervals?

A. So that repairs can be made without tearing down the whole wall.

Q. How is the foundation for a boiler usually prepared?

A. By laying a bed of concrete upon which a wall of stone is laid in cement.

Q. Does the settings of water tube boilers differ from the settings of horizontal tubular boilers?



A Gate Valve.

Fig. 64.

A. A valve to supply steam at less than boiler pressure.

Q. What is meant by a double seat or double beat valve?

A. It is a valve which presents two outlets for the steam or water.

Q. How should all steam valves be connected?

A. In such a manner that the valve closes against the constant steam pressure.

Q. Of what material are pipes used in a steam plant made?

A. They are now mostly made of wrought iron.

Q. What advantage has wrought iron over cast iron for steam pipe?

A. It is stronger and lighter.

Q. Of what are pipe fittings mostly made?

A. Cast iron, malleable iron and steel.

Q. Of what should **all** pipe fittings for large pipe in **high pressure steam plants** be made?

A. Of steel.

Q. Should cast iron fittings be used where they will be exposed to the fire or hot gases?

A. No, steel fittings alone should be used.

Q. How is the size of gas, or the ordinary black pipe usually designated?

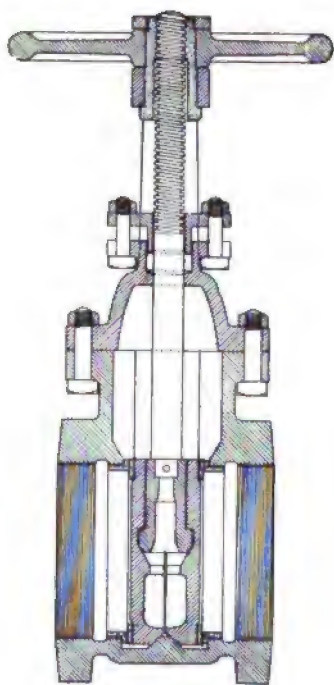
A. By its **internal** diameter.

Q. Are boiler tubes designated in the same way?

A. No, their size is computed from the **external** diameter.

Q. Why is this distinction made?

A. Because boiler tubes are made much more accurate as to size than ordinary black pipe, the outside surface being made **smooth**, which is not the case with pipe.



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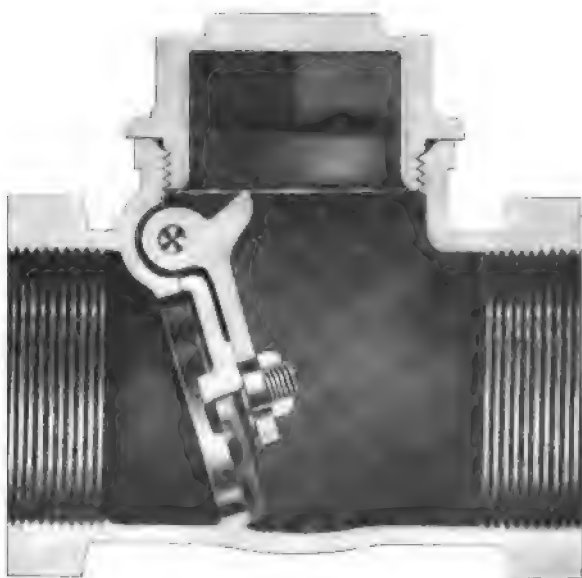
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A Swing Check Valve.
Fig. 65.

Q. Is a bushing and a reducer used for the same purpose in pipe work?

A. Yes, but a reducer makes a much nicer appearance.

Q. What are the main considerations in piping a steam plant?

A. (1) The size of the pipes; (2) the arrangement and construction of the pipes; (3) the method of providing for expansion; (4) proper drainage.

Q. How are steam pipes generally proportioned?

A. So as to permit a velocity of 6,000 feet per minute of flow of steam in pipes carrying **live** steam, and 4,000 feet per minute in **exhaust** pipes.

Q. How is provision made for the expansion and contraction of pipe?

A. By the use of expansion joints, or simply bends in the pipes.

Q. How much is the expansion per 100 feet of length in steam pipes? -

A. About $1\frac{1}{2}$ inches per 100 feet.

Q. How are expansion joints generally constructed?

A. They are simply slip joints, and their usual construction is shown in Fig. 67.

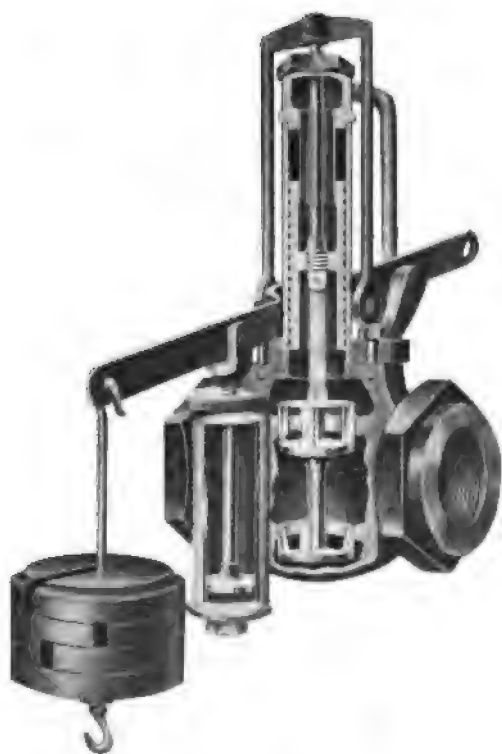
Q. What is a goose-neck?

A. It is simply a curve or bend in a pipe as shown in Fig. 68. The curved form enables it to take up all the expansion or contraction not only of the steam pipe, but also its own expansion or contraction.

Q. How should the curve or bend always be placed?

A. Upwards, in order that no water may collect in the bend.

Q. How should all steam pipes be arranged?



Sectional View of a Reducing Valve.

Fig. 66.

A. So that no pockets or angles are formed in which water may collect.

Q. What is a "water hammer?"

A. It is the steam coming in contact with the water which collects in the pipe, producing a noise like the blow of a hammer.

Q. Is the pressure produced by water hammer considered dangerous?

A. Yes, but experience has shown that it is not capable of producing the amount of damage generally believed.

Q. Should a consulting engineer be a good stationary engineer?

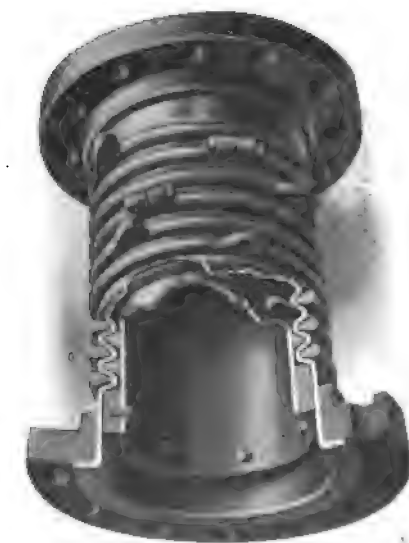
A. Yes, if he expects to design or install steam power plants.

Q. Should he be competent to operate such a plant?

A. Yes, in order to design such a plant so that it can be successfully operated by another.

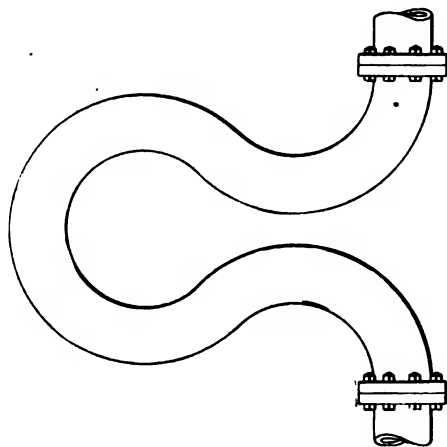
Q. Should a stationary engineer be able to design and install a steam plant?

A. Yes, for he cannot successfully operate it unless he fully understands every piece of machinery in his charge, and how it can be most economically operated.



Expansion Joint.

Fig. 67.



A Gooseneck.

Fig. 68.

STANDARD DIMENSIONS OF WROUGHT IRON AND STEEL STEAM, GAS AND WATER PIPE

Diameter.			Circumference.		Transverse Areas.			Length of Pipe per Square Foot of		Length of Pipe Containing one Cubic Foot.	Nominal Weight per Foot.	Number of Threads per Inch of Bore.
Nominal	Actual	Approximate Internal Diameter	External.	Internal.	External.	Internal.	Metal.	External Surface.	Internal Surface.	Feet.	Pounds.	
Inch.	Inches.	Inches.	Inches.	Inches.	Sq. Inch.	Sq. Inch.	Sq. Inch.	Feet.	Feet.			
1	.405	.27	1.272	.848	.129	.0573	.0717	9.44	14.15	251.3	.241	27
1	.54	.364	1.696	1.144	.220	.1041	.1240	7.075	10.40	1383.3	.42	18
1	.675	.404	2.121	1.552	.358	.1917	.1663	5.657	7.73	751.2	.559	18
1	.84	.623	2.630	1.957	.554	.3048	.2402	4.547	6.13	472.4	.837	14
1	1.05	.824	3.209	2.589	.866	.5133	.3327	3.637	4.635	270.	1.115	14
1	1.315	1.048	4.131	3.292	1.358	.8626	.4954	2.904	3.645	166.9	1.668	14
1	1.60	1.38	5.215	4.335	2.164	1.496	.668	2.301	2.768	106.25	2.244	14
1	1.9	1.611	6.404	5.061	2.835	2.038	.707	2.01	2.371	70.66	2.678	11
1	2.375	2.067	7.461	6.404	4.433	3.356	1.074	1.608	1.848	42.91	3.609	11
2	2.875	2.468	10.032	7.753	6.402	4.784	1.768	1.328	1.547	30.1	5.736	8
2	3.5	3.067	12.560	9.636	9.621	7.388	2.243	1.091	1.245	10.5	7.536	8
2	4.5	3.548	14.137	11.146	12.566	9.887	2.670	.955	1.077	14.57	9.001	8
2	5.508	4.026	17.773	14.137	15.004	12.73	3.174	.840	.940	11.31	10.665	8
2	6.623	5.045	20.813	15.849	19.035	15.061	3.674	.769	.848	9.02	12.442	8
2	7.025	5.065	23.055	17.773	22.063	18.888	4.316	.687	.737	7.2	14.562	8
2	8.025	5.082	27.000	20.813	24.472	20.888	5.384	.577	.63	4.98	18.762	8
2	9.025	5.097	30.238	23.055	28.064	24.738	6.566	.501	.546	3.88	23.271	8
2	10.025	5.112	33.772	25.876	31.426	28.064	7.866	.443	.478	2.88	28.177	8
2	11.025	5.127	37.472	28.064	34.772	31.426	9.284	.397	.427	2.09	33.701	8
2	12.025	5.142	40.655	30.238	38.064	34.772	10.83	.355	.382	1.52	40.005	8
2	13.025	5.157	43.358	32.558	40.914	37.472	12.401	.325	.347	1.11	45.028	8
2	14.025	5.172	45.655	34.772	43.358	40.914	14.570	.299	.310	0.8	48.985	8

Table No. 8.

CHAPTER V.

BOILER ACCESSORIES.

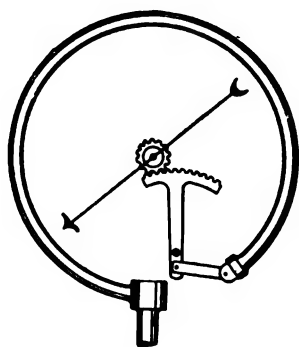
Boiler Attachments.—The principal attachment to any boiler is the **furnace**, which varies in shapes and size with the type of boiler and the kind of fuel to be burned. The furnace consists of the fire and ash doors, grate bars, bridge wall and ash pit. The principal requirements of all properly constructed furnaces is a uniform and abundant air supply to the under side of the grate, so as to insure **complete combustion**.

In order to accomplish this there must be ample air space above the fire to permit of all the gases to be entirely consumed before leaving the furnace. Should it not be possible to have sufficient space between the grate and the shell of the boiler, then a combustion chamber must be used in which the combustion can be completed. To insure complete combustion, most all furnaces are provided with a combustion chamber.

Furnaces are designated either as **straight draft** or **down draft** furnaces, according to the direction taken by the draft, the majority of furnaces being straight draft furnaces.

The **furnace door** is usually of cast iron, provided in the center with a circular draft plate through which air is admitted to the fire above the grates.

Steam Pressure Gauge.—In Fig. 69 is shown a sectional cut of the **Bourdon Pressure Gauge**, which is a gauge universally used. As has been previously explained this gauge is constructed upon the principle that a flat tube, curved to almost a complete circle and closed at one end, tends to become **straight** when subjected to internal pressure. One end of this tube being fixed, the



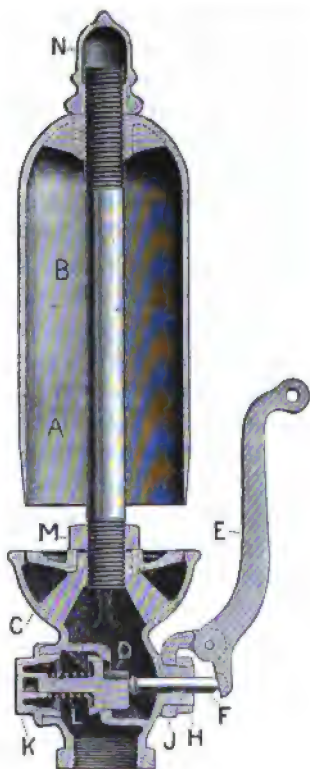
Sectional View of the Bourdon Steam Gauge.
Fig. 69.

internal pressure in straightening the tube, moves the other end. By means of levers, a curved rack and a pinion, the motion of the **free end** is greatly multiplied and indicated by a needle which is attached to the pinion. This needle is made to move over a dial which has been graduated, that is divided into spaces, so as to agree with the mercury column which is usually adopted as the standard measurement of pressure, or with a standard gauge. The back lash of the levers is taken up by a hair spring. A **vacuum gauge** is similar in every respect to the above described pressure gauge with a single exception that the curved tube is turned in the **opposite** direction, so that the needle is made to move with a **decrease** of pressure, which indicates the decrease of pressure below that of the atmosphere.

The Steam Whistle.—This boiler attachment is used for signaling purposes. There are two kinds, known as the **bell whistle** and the **organ tube whistle**, the latter having now almost superceded the bell whistle on account of the simplicity of its construction and superior tone. Great care should be taken to keep the whistle pipe free from water, so that the whistle will sound as soon as the steam is turned on. Fig. 70 shows a common form of steam whistle. The hollow base has a narrow circular orifice that communicates with the steam pipe. The steam compresses the air contained in the bell of the whistle, thereby causing vibration to continue as long as the steam is permitted to flow, and the communications of these vibrations to the surrounding atmosphere produces the sound.

In Fig. 70 is shown a sectional view of the Lunkenhoimer steam whistle.

Directions for Connecting.—To give best results, whistles should be placed as nearly as possible over the



Sectional View of a Steam Whistle.
Fig. 70.

boiler and above surrounding buildings, so that the sound will not be obstructed. If they are so placed that there are a number of bends and off-sets in the connecting pipes, or the whistle is a considerable distance from the boiler, the whistle valve should be directly under the whistle and a second valve (an ordinary stop valve) should be placed at the bottom of the pipe. Means should be provided for draining the connecting pipes by placing a small drain cock directly above the lower valve. If the whistle is not too far from the boiler, the whistle valve can be placed at the bottom of the connecting pipes instead of directly under the whistle. When operating a whistle connected as above, the drain cock should be first opened to allow any condensed water (which may have accumulated in the pipes) to escape. If a stop valve is used at the bottom of the pipe, open same a moment or so before operating the whistle valve so as to heat the pipe and get dry steam to the whistle. They should not be attached to steam pipes used to supply steam for other purposes.

Use as little lead or pipe joint grease as possible in connecting the pipes, and blow out thoroughly before connecting the whistle.

Take the steam supply directly from the dome of the boiler, if possible, so that it will be dry and of maximum pressure, and avoid all unnecessary elbows, etc.

The whistle bell must be set at the proper distance from the slot in the top of the base to suit the steam pressure. To regulate this: loosen the acorn-shaped lock nut on top of the bell and screw the bell down or up until it blows satisfactorily. For higher pressures screw the bell up and for lower, down. When properly adjusted be sure to again tighten the lock nut.

Feed-Water Heaters.—The advantage of introducing the feed-water into the boiler at a high temperature is the saving in the fuel, and the avoidance of the strains produced upon the boiler by the introduction of cold feed-water.

Economy.—The great economy of using the waste heat in exhaust steam for heating the feed-water can be clearly seen from the following calculation:

When the feed-water enters the boiler at 60 degrees Fahrenheit, and the boiler is furnishing steam at 100 pounds gauge pressure then the number of heat units required to change a pound of water at 60 degrees into steam at 100 pounds pressure is equal to 1,157 B. T. U., as can be seen from the Steam Tables. Therefore, the number of heat units gained by utilizing the exhaust steam for heating the feed water is $210 - 60 = 150$ B. T. U., which is a gain of about 12 per cent.

In using the steam tables always be careful to convert gauge pressure into absolute by adding 15 pounds, which is about the pressure of the atmosphere. Hence, the absolute pressure of 100 pounds gauge pressure is 115 pounds.

Classification of Feed-Water Heaters.—There are two separate and distinct classes of feed-water heaters, both of which classes are in general use. The first class is known as closed heaters, and the second class as open heaters.

Closed Heater.—In this class of heaters the feed-water is not exposed to the atmosphere, but is subjected to the temperature of the steam by bringing the metal tubes through which the feed-water is pumped, in contact with the steam. In this form of heater the water in passing through the tubes extracts the heat from the exhaust steam contained in the shell of the heater. The

feed-water is therefore pumped **through** the heater to the boiler, the heater being **between** the pump and the boiler. This permits the pump to handle the water **cold**, which is a decided advantage, as it is much easier to pump cold water than hot water.

This form of heater is called a **closed** heater, since the water to be heated is confined in tubes or pipes. The exhaust steam does not come into contact with the water to be heated, but surrounds the tubes or pipes in the heater, and in this way heating the water before its entrance into the boiler. In the closed type of heater the water is usually caused to circulate through tubes arranged in different ways, while the exhaust steam envelopes the tubes from end to end in passing through the heater from the inlet to the outlet of same. Occasionally, this form of heater is constructed with the water outside and the steam inside the tubes, but the former method of heating gives a much more rapid circulation, and is therefore much more efficient.

Open Heater.—This class of heater can be subdivided into two sub-classes, being known as **direct contact open heaters**, and **coil heaters**. In the first subclass, the exhaust steam comes into **direct** contact with the water, which readily absorbs the heat of the steam.

In a **coil heater** the water does not come into contact with the exhaust steam, but it is heated by the exhaust steam which passes through coils of pipe submerged in a suitable vessel or heater containing the water. This vessel or heater is open at the top, thus permitting the water to be exposed to the atmosphere. This form of heater is rarely used, it being neither efficient nor economical.

In the **open direct contact heater**, which is the most generally used form of heater, the exhaust steam and

feed-water are brought directly into contact and made to **mix**, thereby causing most of the steam to be condensed and imparting its heat to the water. This form of heater must always be placed on the **suction** side of the feed pipe, and hence the **pump** is between it and the boiler.

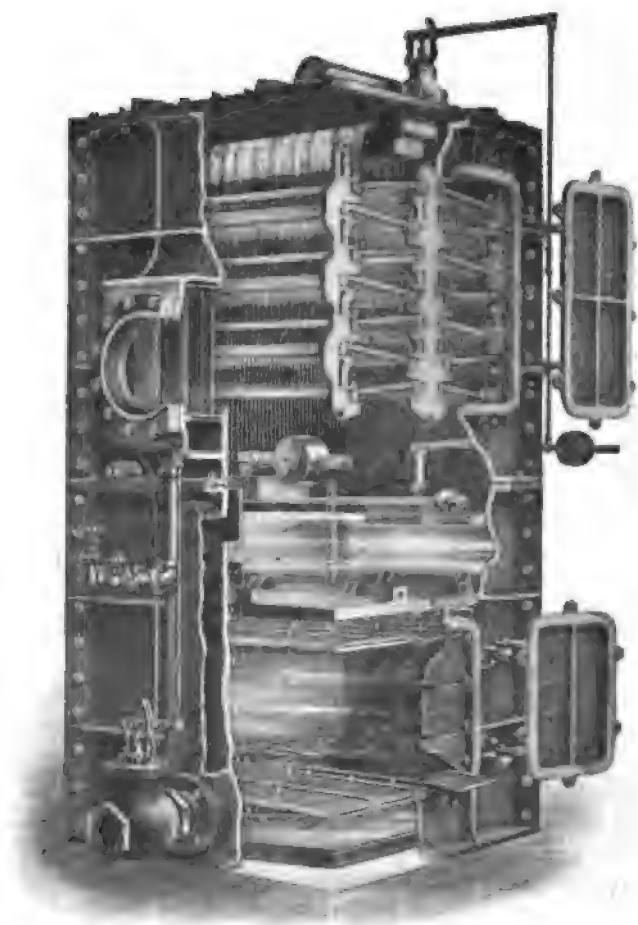
Disadvantages.—As the exhaust steam and water are brought together, all the oil or grease carried over from the engine in the exhaust steam will mingle with the heated water, necessitating some mechanical means to separate the two, so that the water fed to the boiler will be free from it. This is usually done by **filtration**, or by an oil **separator**. As the pump is between the heater and the boiler it requires the pump to handle hot water, which requires the heater to be placed **higher** than the pump.

With this form of heater a temperature of 210 degrees should be maintained, which in addition to the saving in fuel, is also desirable as at this temperature most of the scale forming substances, with the exception of the sulphates, are precipitated, so that this form of heater also acts as a **water purifier**.

Object.—The object of the feed-water heater is to reclaim as far as possible all of the heat in the waste steam, and to also act as a feed-water purifier. The feed-water heater utilizes the **waste steam**, while the **waste gases** are utilized by an **economizer**.

Location.—The feed-water heater should be placed at any convenient point in the exhaust steam line, although it is better to locate it as **near** the engine as practical.

In Fig. 71 is shown a common form of a direct contact open heater. Table No. 9 shows the great economy from the use of feed-water heaters.



Sectional View of the Webster.
Exhaust Steam Feed-Water Heater and Purifier.
Fig. 71.

Feed-Water Purifier.—As most of the scale-forming substances in water become insoluble in precipitate when the water which contains them in solution is heated to a sufficiently high temperature, a feed-water purifier is simply an apparatus in which either live or exhaust steam is used to heat the feed-water for this purpose. In **live steam purifiers** the water is heated by the live steam at full boiler pressure. In order to raise the temperature of the water to 290 degrees Fahrenheit required to precipitate the principal scale-making element, sulphate of lime, the heater is subjected to the full boiler pressure, the water being pumped into it, and it then entering the boiler by gravity. A temperature of about 212 degrees Fahrenheit is necessary to precipitate the carbonate of lime.

This type of heater is called a live steam purifier to distinguish it from those in which the water is heated at atmospheric pressure, or a pressure slightly above it. A live steam feed-water purifier cannot be as economical as a feed-water heater in which the exhaust steam alone is used, as where the exhaust steam is used for heating the water, it is then taken from a source of **waste**. On the contrary when the **live** steam is used for this purpose, the steam is taken from the boiler, and there can be no direct saving in fuel, but only an **indirect** saving by the prevention of accumulation of scale in the boiler, which is always a source of waste of fuel.

In Fig. 101 is illustrated a common form of a live steam feed-water heater and purifier.

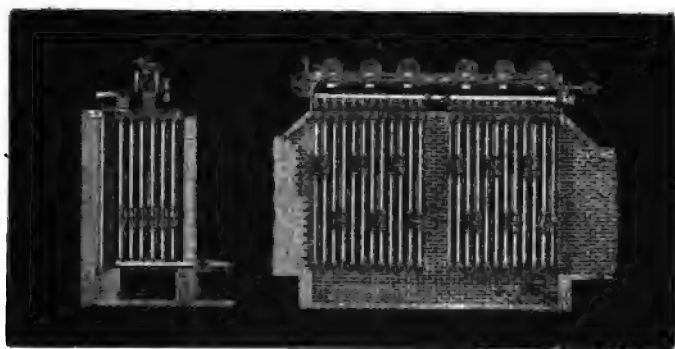
Economizer.—The object of the economizer is to reclaim as far as possible the heat in the **gases** escaping into the chimney, and to use this heat to raise the temperature of the feed-water. The temperature of the gases on entering the chimney is usually from 400 to

600 degrees Fahrenheit. By lowering this temperature to 250 to 300 degrees, quite a saving of fuel is obtained. The **draft** of the chimney, however, depends upon the **temperature** of these gases, and this loss of temperature must be made up by increasing the **height** of the chimney in order to maintain the draft.

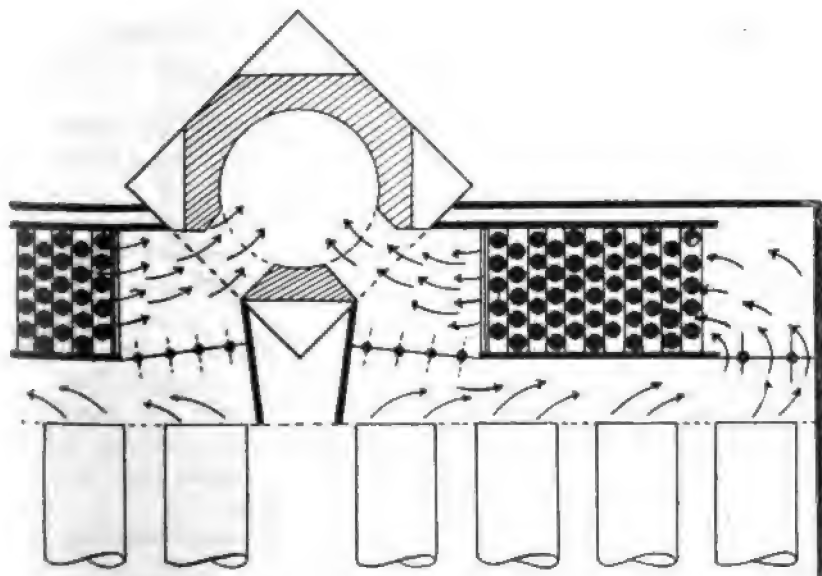
Fig. 72 shows the position of an economizer with respect to the boiler and chimney. As can be seen, it is placed directly in the flue. The hot gases from the boiler pass through the row of tubes on their way to the chimney, thus heating the feed-water which is made to circulate through these tubes. In this way the feed-water may be heated to as high as 350 degrees Fahrenheit, and the temperature of the gases reduced to about 300 degrees Fahrenheit.

Steam and Oil Separators.—A separator is an apparatus designed to remove the water, oil, dirt and other impurities from a current of steam flowing through a pipe. When it is intended to separate the steam from the water, the separator is placed on the main pipe leading from the boiler to the engine, and as **close** as possible to the engine. When it is used to remove the **grease** and dirt from **exhaust steam** before using as feed-water for the boiler, the separator is placed in the exhaust pipe leading from the engine to the condenser, or heater.

Classification.—Steam separators are divided into two general classes, viz.: (1) **Baffle plate separators**; (2) **Centrifugal separators**. In the first class, the steam comes in contact with the baffle plates placed at right angles to its direction of flow, thus sharply changing the direction of flow of steam. In a **centrifugal separator** the steam is given a whirling motion in flowing through the apparatus, and by this whirling motion the water is separated from the steam.



An Economizer, Showing Its Location.
Fig. 72.



Sectional View of Economizer.
Fig. 72.

Action.—The principle of all separators depends on **inertia**. Since water or oil is much heavier than steam, their inertia is much greater than that of the steam. Consequently, when the current of steam comes in contact with the baffle plate, the steam changes its direction with ease, but the heavier particles of water or oil, by reason of their inertia are dashed against the baffle plate, thus separating them from the steam which flows on to the engine.

Fig. 73 illustrates a common form of a horizontal and vertical centrifugal separator, which is known as the Detroit Separator. In Fig. 78 is shown the separator connected **direct** to the engine.

Steam Trap.—This is an appliance for **removing** the water of condensation from steam pipes, separators, and similar apparatus without the waste of steam.

Fig. 74 shows the usual connection between a steam trap and separator, in which 1 is the separator and 2 the steam trap.

Classification.—Steam traps are divided into two general classes, being viz.: **open traps** and **closed traps**.

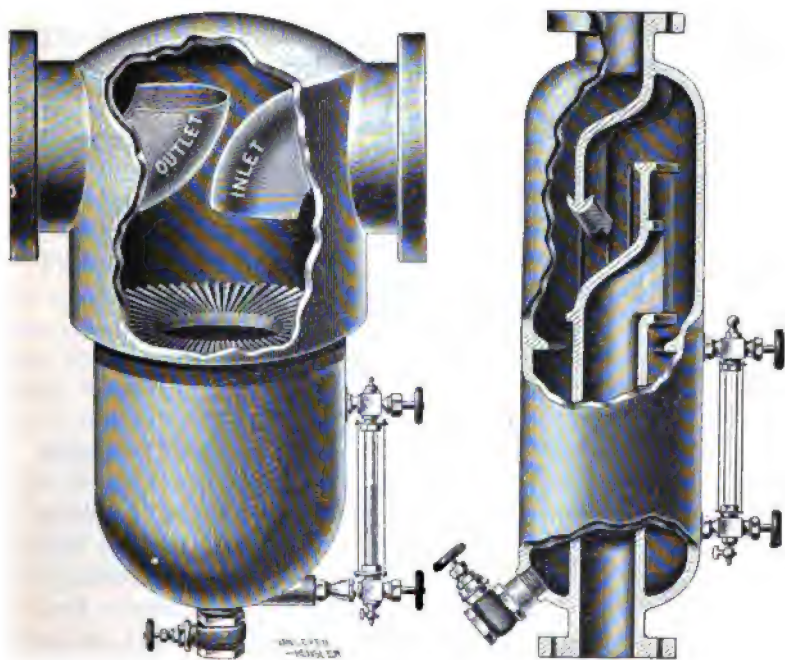
Open Traps.—This is a trap that is so constructed that it can only discharge into a vessel in which there is a **lower pressure** than in the trap. Should it become necessary for it to discharge into a higher pressure, then the trap must be **elevated** high enough above the vessel in which it is to discharge, to have a head of water in it sufficiently great to create a pressure higher than exists in the vessel into which it is to discharge.

Fig. 75 shows a common form of an open **float** trap.

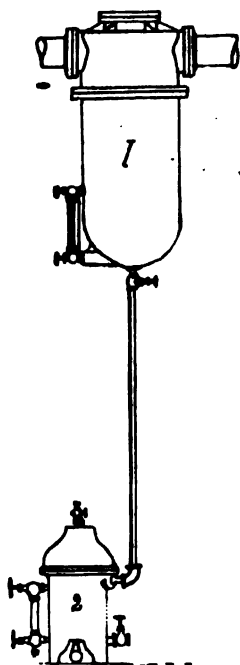
Fig. 76 shows an open **bucket** trap.

Fig. 77 shows an **expansion** trap.

Fig. 111 shows an **open trap** so placed as to return the condensation direct into the boiler.



Sectional View of a Horizontal and Vertical Centrifugal Separator.
Fig. 73.



A Steam Trap Connected to Separator.
Fig. 74.

Closed Trap.—Such a trap is so constructed as to be able to discharge the water of condensation from a system in which there is low pressure, into a vessel in which there is a high pressure.

This form of trap is not generally used, it being more economical to use the cheaper open trap for this purpose.

Injector and Inspirator.—The injector is an apparatus for forcing the feed-water into a steam boiler. It was invented in 1858 by the French scientist, Henri Giffard, and since that time has been universally used.

Principle of Action.—The velocity of the steam carries the air inside the injector with it, and thus creates a partial vacuum into which the feed water flows. The steam then imparts a portion of its velocity to this water, giving it sufficient momentum to force open the check valves and enter the boiler.

Essential Parts.—Fig. 79 shows the essential parts of an injector by means of which the injector performs its work. Steam is admitted through (a) and flows through the nozzle with a high velocity, passes through the combining tube (d) and out through the overflow (e) and nozzle (g). This current of steam carries the air in the chamber (b) with it, thus forming a partial vacuum; the pressure of the atmosphere then forces the water from the supply into the chamber and into the combining tube (d). In (d) the steam and water are **combined**, with the result that the steam imparts a great deal of its velocity to the water and at the same time is condensed. This forms a jet of water that flows from the combining tube (d) with such a **high velocity** that it passes over the overflow (e) and into the discharge pipe (h), the energy in the water being great enough to



A Float Steam Trap.
Fig. 75.

overcome the pressure in the boiler. The water thus flows past the check valve (i) into the boiler.

The check valve is not a part of the injector itself, but it is a most essential part of the installation.

Steam Supply.—When the injector is working properly the feed-water is forced into the boiler in a steady unbroken jet, but should the feed-water be **too hot** to condense the steam used to operate the injector, then the steam owing to its lightness will not be forced into the boiler, but will flow out of the overflow.

Should the supply of steam be **too large**, then all of it will not condense in the combining tube and it will be discharged from the overflow nozzle. When the supply of steam is **too small**, its momentum is not then sufficient to carry it into the discharge pipe against the pressure in the boiler, and the water is discharged out of the overflow nozzle.

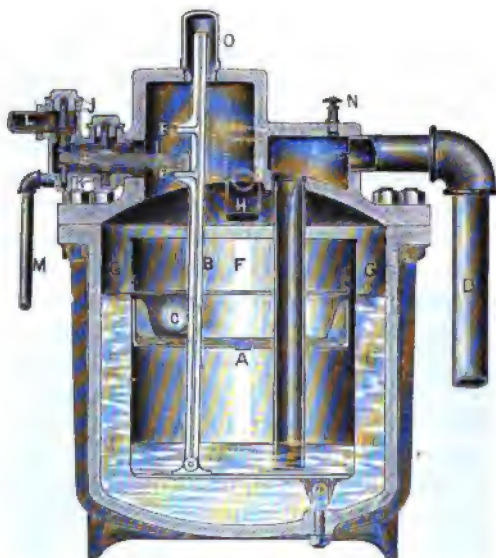
It is only necessary to watch the overflow nozzle in order to know when the injector is working properly.

Range of an Injector.—This term refers to the steam pressure at which an injector will start, and the steam pressure at which it ceases to work.

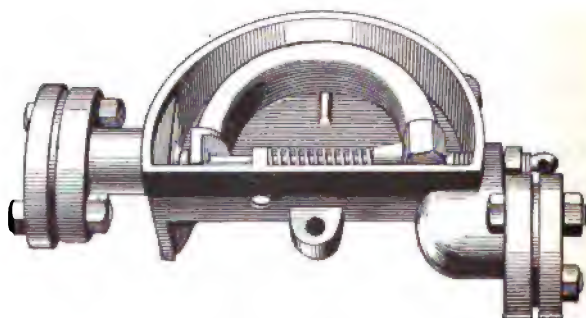
Table No. 10 shows the **range** of injectors, with temperature of the feed-water, as given by the International Correspondence Schools, together with Fig. 79.

Connections of Injector to Boiler.—In Fig. 80 is shown the proper way to connect up the Penberthy injector, which is a well known type of an automatic injector.

Parts of Injector as Shown in Fig. 80.—B, Body of Injector. D, Globe Valve in Steam Pipe. F, Check Valve in Delivery Pipe. G, Globe Valve in Delivery Pipe. H, Globe Valve in Suction Pipe. J, Water Supply taken from below Injector. K, Water Supply taken from Overhead Tank. L, Waste Pipe from Overflow.



A Bucket Steam Trap.
Fig. 76.



An Expansion Trap.
Fig. 77.

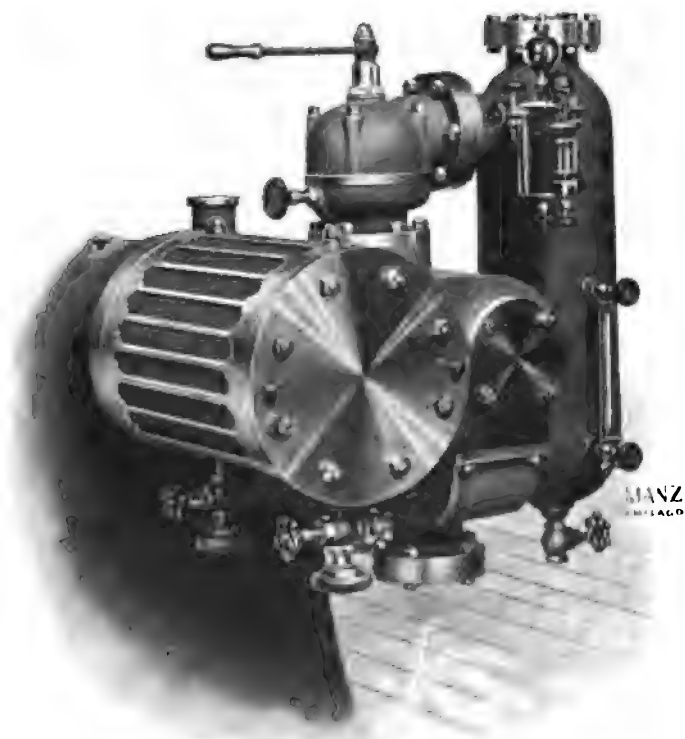
M, Second Globe Valve in Water Supply Pipe where an Overhead Tank is used or supply is taken from Water Works Pressure.

Direction.—**Steam Pipe "D"** should always be same size as injector connections, and must be connected to boiler at the highest possible point, and independently of any other pipe, in order to insure best results. This pipe must be blown out with steam before connecting injector.

Suction Pipe "H" must always be as large as injector connections, and where lift is over 10 feet, should be one or two sizes larger, reducing to injector size as near injector as possible, and having a globe valve same size as larger pipe. Be sure and put a **globe valve** (not a straightway) in the water supply pipe.

On a Long Lift a foot valve should be placed on lower end of suction pipe. Without a foot valve, every time the injector is started the air must all be exhausted from the suction pipe before the water can reach the injector, and considerable steam is wasted. With a foot valve, the water is held in the pipe when injector is stopped and is there when starting again, so that the saving in steam will soon pay for the cost of this valve.

Where the water pressure is heavy, such as is usual where there is a city water works, to facilitate starting on low steam, many persons use two globe valves, "H" and "M," in the water supply pipe, one as near the injector as possible and the other several feet away, forming a "well" between the two. The far away valve "M" can then be used to reduce the pressure and the one near the injector for regulating the water supply. The same result can be obtained by using a water supply pipe and valve one size smaller than injector connections.



Steam Separator Connection to Engine.

Fig. 78.

Its Economic Value.—The protection afforded is in itself sufficient reason for equipping every boiler with this device. But in addition there are several economic advantages to be gained from its use, all of which are the natural result of keeping the water steady at the proper level.

A Saving in Fuel.—When the water level is constantly changing there is bound to be great loss of heat and fuel. If the water is too high an unnecessary amount of heat is required, involving wasteful consumption of fuel. If it is too low it necessitates the sudden forcing in of a large quantity of water at a lower temperature to absorb the heat and reduce the steam pressure. Another waste of heat, fuel and money.

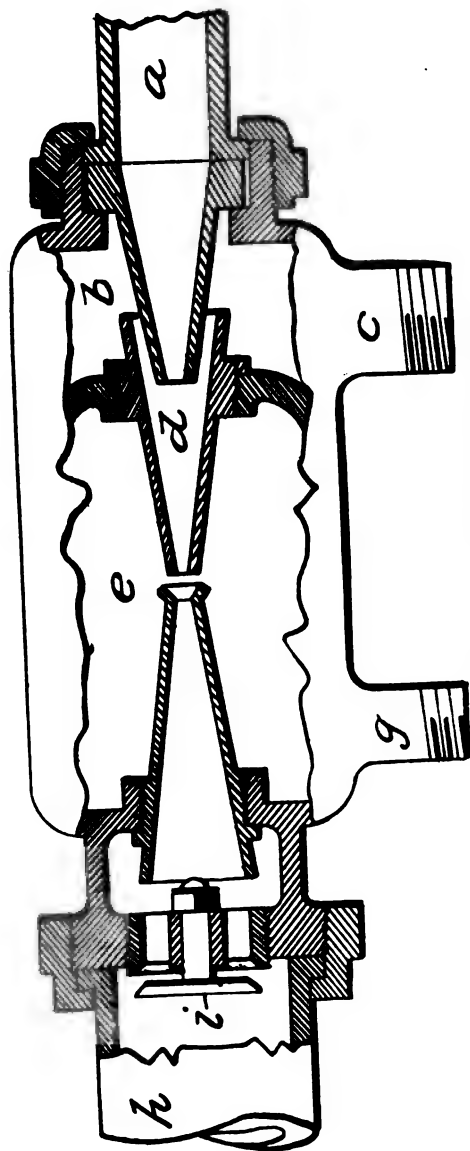
Dry Steam.—High water in the boiler is not only the cause of wet steam, but gives opportunity for water to be drawn over to the engine in considerable quantities. A blown out cylinder head, or possibly the complete wrecking of the engine may follow. The gain in engine efficiency resulting from steady steam pressure and the use of dry, elastic steam, is too well understood to need discussion.

Increased Durability of Boilers.—Another effect of unsteady water is to cause fluctuations of temperature and pressure, which in turn result in constant expansion and contraction of the boiler. This racking and straining is destructive to the life of the boiler and the source of frequent repair bills as well.

Fig. 97. shows a common form of a **safety water column.**

FURNACE ATTACHMENTS.

Grates.—The grates should not be larger than can be conveniently cleaned and fired. Two fire doors should be provided when they are more than 4 feet wide.



Essential Parts of an Indicator or Inspirator.
Fig. 79.

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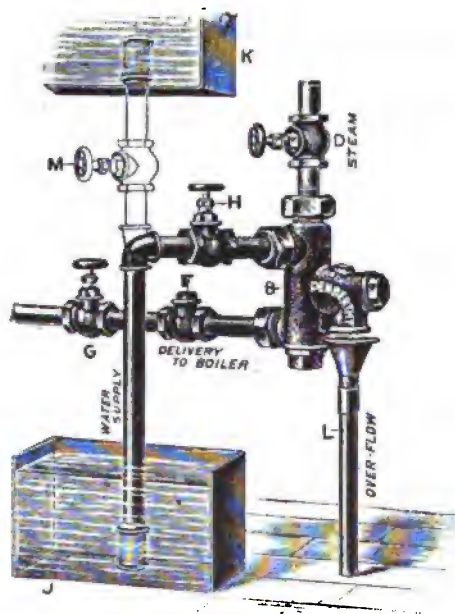
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Connections of Injector to Boiler.
Fig. 80.

The grates are usually inclined slightly to the rear to aid in firing, and also to permit a freer access of the air.

Grate Bars.—They are usually made of **cast iron** and their shape and size depend on the character of furnace or fire box and the fuel to be burned on them.

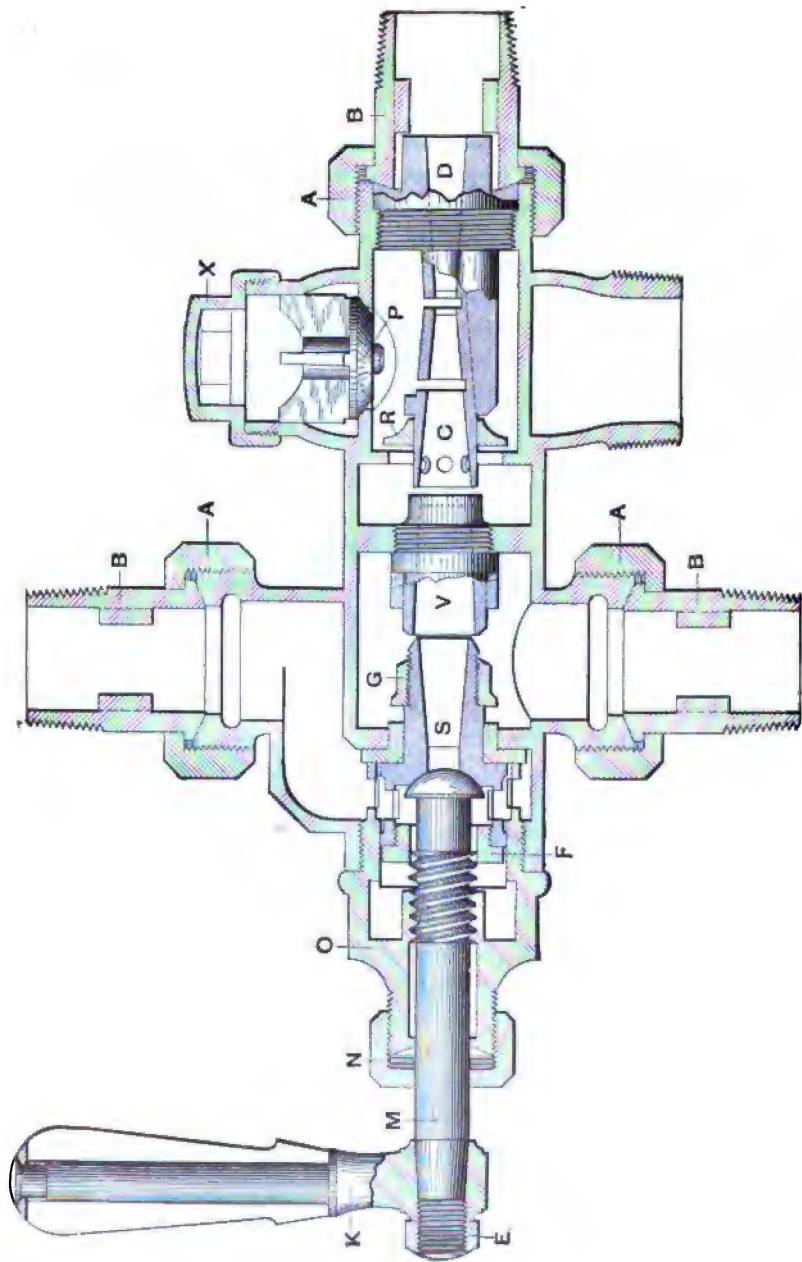
In Fig. 82 is shown the most common forms used. The circular grate A is used in **vertical boilers**; the herring-bone is also much used under vertical boilers. The form B is used for burning **wood** and **sawdust**. The form D is the ordinary form used in all **coal fired** furnaces.

For the burning of **fine coal**, the perforations, or air spaces, must be not over from 30 to 50 per cent of the total area of the grate. For **anthracite coal** the spaces must also be made small, but for **bituminous coal** the spaces must be made much larger. The grate bars should not be more than 3 feet long and 3 inches deep, with a thickness of $\frac{3}{4}$ -inch at the top and $\frac{3}{8}$ -inch thickness at the bottom. The **air space** left between each bar should be about $\frac{1}{2}$ inch. In Fig. 82, E is a cross sectional view of two grate bars of the ordinary type used in coal fired furnaces, which sectional view shows proper measurements and spacing.

Grate area is designated by the **square foot**, the ordinary size furnaces containing about 25 square feet of grate area.

Dead Plate.—This is simply a flat iron plate just inside the furnace door, which furnishes a support for the fire brick lining of the front of the furnace, and is also used to **coke** the coal upon it before burning.

This is done by placing the coal on the dead plate, and letting it become heated and the distilled gases consumed before pushing the coal back on the grate.



Sectional View of the Metropolltan Injector.
Fig. 81.

Bridge.—This is a wall built at the back end of the grate, and forming the rear end of the furnace. The purpose of this bridge wall is to bring the flame and heated gases in **close contact** with the heating surface of the boiler. The distance between the bridge and the boiler shell should be from 6 to 10 inches according to the size of the furnace and the character of the fuel to be burned.

Damper.—This is an apparatus to keep the steam pressure **constant** by regulating the draft. The draft is regulated by controlling the volume of gases permitted to pass into the chimney. This in turn regulates the **intensity** of the fire and the **generation** of steam.

While there are a great variety of damper regulators, many of which are automatically operated by the pressure of the steam on a diaphragm, they are generally constructed upon the same principles. **Automatic damper** regulators are used mostly in **low pressure heating** plants. Fig. 126 is a cut of a **damper regulator** in general use.

Mechanical Stokers.—While shaking grates are designed to permit the cleaning of the fire without opening the fire doors, and to further facilitate the cleaning of same by not exposing the firemen to excessive heat, **mechanical stokers** were devised to save the labor of **feeding** furnaces by hand. There are a great many styles in use, the first mechanical stoker having been invented by James Watt.

One form in general use consists of longitudinal bars connected by links forming an endless chain. The coal is charged into a hopper and by it delivered at the front of the boiler on this endless chain. The moving of the grate from the front to the rear of the furnace,

moves the coal into the furnace, and then disposes of the ashes and clinkers when it reaches the back of the furnace.

Classification.—Mechanical stokers are divided into two general classes, viz. **over-feed** and **under-feed**.

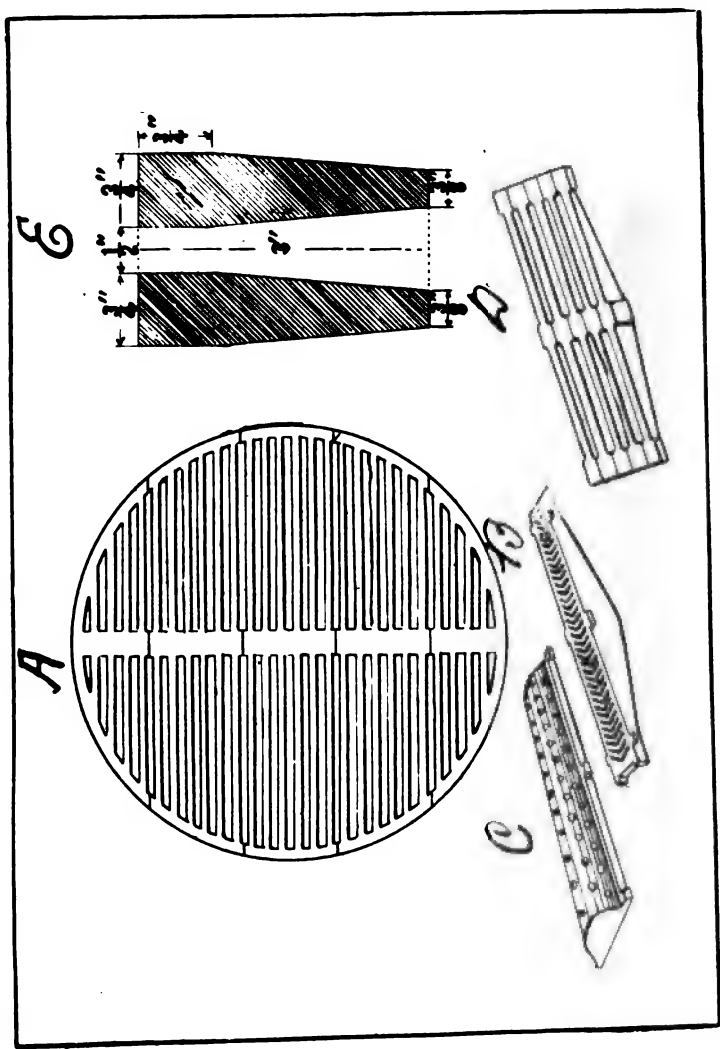
Over-Feed.—In this design of stoker the coal is fed on a coking plate, where the volatile matter is distilled off by the heat of the furnace and mixed with the proper amount of air. The coke remaining is then carried forward onto the grates, where it is burned.

Under-Feed.—In this design of stoker, the coal is forced by some mechanical device into a chamber **under** the mass of burning fuel in the furnace. The coke which is formed is pushed upwards by the fresh coal that is fed into the hopper, and burns above the coking chamber on suitable grates on which it falls.

Advantages and Disadvantages.—There is little or no saving in the use of mechanical stokers in **small plants**, and so far as the **economy** is concerned but little saving in the use of automatic stokers over hand firing in large plants. The chief advantages obtained from the use of mechanical stokers is the **relief** on the firemen from much of the severe and difficult part of his work, and the saving of **wear** and **tear** on the boiler.

With a mechanical stoker a constant opening of the fire doors is entirely avoided. No **cold** air is therefore admitted under the boilers to cause, not only **great injury** to the boiler itself and **waste** of fuel, but great hardship on the fireman. There is a further saving of **labor**, as with a good mechanical stoker one man can do the work of several.

As more perfect combustion can be obtained with mechanical stokers than with hand firing, owing to the



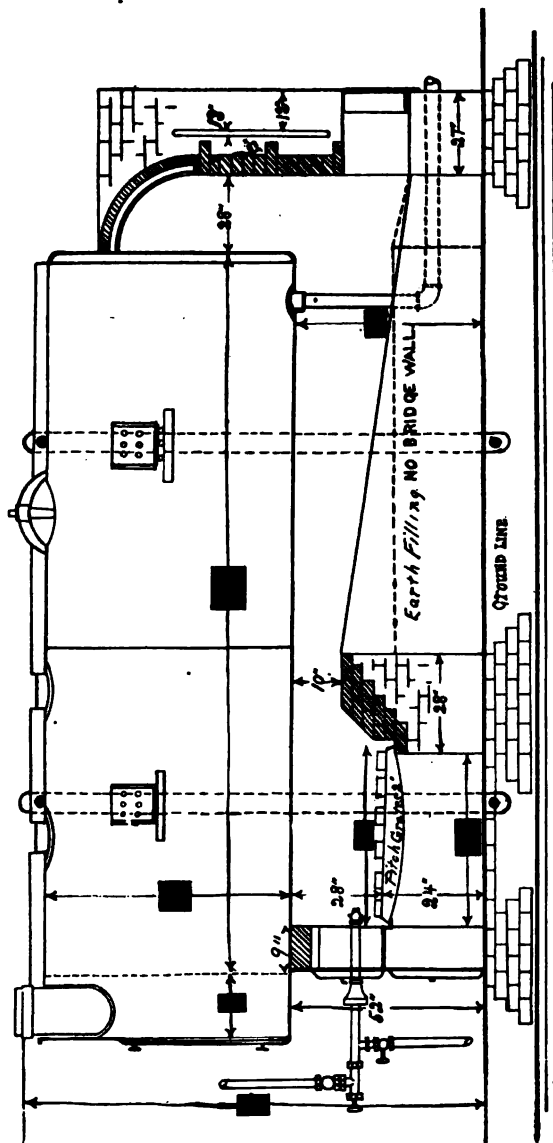
Usual Forms of Furnace Grates.
Fig. 82.



Crude Oil and Natural Gas Burners.
Fig. 83.

even and uniform rate the coal is fed to the furnace, much better results can therefore be obtained in **smoke prevention** by their use.

In Fig. 125 is shown the common form of an Under-Feed Mechanical Stoker, and in Fig. 124 is shown a Front-Feed Stoker.



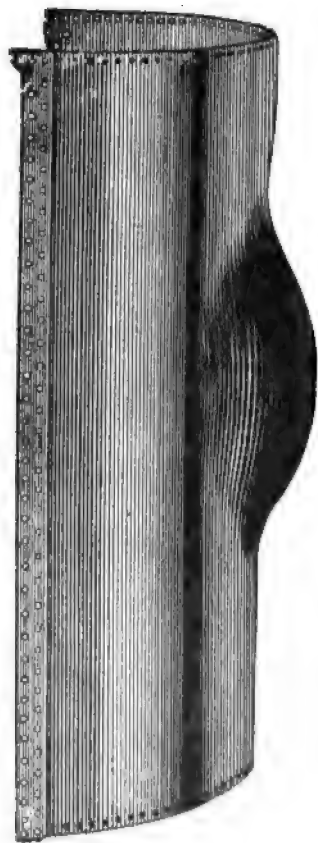
Crude Oil Burner Installed. (Burner much enlarged in length.)
Fig. 84.

FEED-WATER HEATERS.

Percentage of Saving for Each Degree of Increase in Temperature of Feed-water Heated by Waste Steam.

Initial Temperature of Feed-water, Degrees		Pressure of Steam in Boiler, Pounds per Square Inch Above Atmosphere											Initial Temperature, Degrees	
0	20	40	60	80	100	120	140	160	180	200				
.0872	.0861	.0855	.0851	.0847	.0844	.0841	.0839	.0837	.0835	.0833			32	
.0878	.0867	.0861	.0856	.0853	.0850	.0847	.0845	.0843	.0841	.0839			40	
.0886	.0875	.0868	.0864	.0860	.0857	.0854	.0852	.0850	.0848	.0846			50	
.0894	.0883	.0876	.0872	.0867	.0864	.0862	.0859	.0856	.0855	.0853			60	
.0902	.0890	.0884	.0879	.0875	.0872	.0869	.0867	.0864	.0862	.0860			70	
.0910	.0898	.0891	.0887	.0883	.0879	.0877	.0874	.0872	.0870	.0868			80	
.0919	.0907	.0900	.0895	.0888	.0887	.0884	.0883	.0879	.0877	.0875			90	
.0927	.0915	.0908	.0903	.0899	.0895	.0892	.0890	.0887	.0885	.0883			100	
.0936	.0923	.0916	.0911	.0907	.0903	.0900	.0898	.0895	.0893	.0891			110	
.0945	.0932	.0925	.0919	.0915	.0911	.0908	.0906	.0903	.0901	.0899			120	
.0954	.0941	.0934	.0928	.0924	.0920	.0917	.0914	.0912	.0909	.0907			130	
.0963	.0950	.0943	.0937	.0932	.0929	.0925	.0923	.0920	.0918	.0916			140	
.0973	.0959	.0951	.0946	.0941	.0937	.0934	.0931	.0929	.0926	.0924			150	
.0982	.0968	.0961	.0955	.0950	.0946	.0943	.0940	.0937	.0935	.0933			160	
.0992	.0978	.0970	.0964	.0959	.0955	.0952	.0949	.0946	.0944	.0941			170	
.1002	.0988	.0981	.0973	.0969	.0965	.0961	.0958	.0955	.0953	.0951			180	
.1012	.0998	.0990	.0983	.0978	.0974	.0971	.0968	.0964	.0962	.0960			190	
.1022	.1008	.1000	.0993	.0988	.0984	.0980	.0977	.0974	.0972	.0969			200	
.1033	.1019	.1010	.1003	.0998	.0994	.0990	.0987	.0984	.0981	.0979			210	
.1043	.1029	.1019	.1013	.1008	.1004	.1000	.0997	.0994	.0991	.0989			220	
.1053	.1039	.1029	.1023	.1018	.1012	.1010	.1007	.1003	.1001	.0999			230	
.1063	.1049	.1039	.1034	.1029	.1024	.1020	.1017	.1013	.1011	.1009			240	
.1073	.1059	.1049	.1043	.1038	.1034	.1030	.1027	.1025	.1022	.1019			250	

Table No. 9.



A Bag or Bulge in Boiler Plate.
Fig. 85.

Vertical Lift: Feet.	Feedwater at 60 .		Feedwater at 75 .		Feedwater at 100 .	
	Starting Pressure.	Stopping Pressure.	Starting Pressure.	Stopping Pressure.	Starting Pressure.	Stopping Pressure.
2	15	155	15	145	20	120
4	18	150	18	140		
6	20	142				
8	25	135	25	125		
10	30	125	30	115	35	90
12	35	118				
14	40	110				
15			50	85	45	70
16	45	102				
18	50	90				
20	55	85	55	75		
22	55	75				

Range of Injectors.

Table No. 10.

CHAPTER VI.

QUESTIONS AND ANSWERS ON PRECEDING CHAPTERS.

Q. What is the principal boiler attachment?

A. The furnace.

Q. Into what classes are furnaces divided?

A. Into straight-draft and down-draft furnaces, according to the direction taken by the draft.

Q. What is a steam pressure gauge?

A. It is a gauge attached to the boiler to indicate the amount of pressure in the boiler.

Q. How is this pressure designated?

A. In the number of pounds per square inch **above** the pressure of the atmosphere.

Q. Is this the **absolute** pressure within the boiler?

A. No; it is the gauge pressure, the absolute pressure being 14.7 pounds in excess of the pressure shown by the gauge.

Q. What is meant by **atmospheric** pressure?

A. It is the pressure that exists on all objects on the surface of the earth. It is not felt by us as it is equalized, i. e., the pressure is exerted equally in all directions.

Q. Is this pressure the greater at the sea level or upon a mountain?

A. It is greater at the sea level, becoming less as the altitude becomes greater.

Q. For what purpose is a **whistle** attached to a steam boiler?

A. For signaling purposes.

Q. What is a feed water heater?

A. It is an apparatus for heating the feed water of a boiler.

Q. What is the object of heating the feed water?

A. To save fuel, and also the boiler, by decreasing the expansion and contraction.

Q. How are feed water heaters classed?

A. Into two classes, designated as **closed** heaters and **open** heaters.

Q. What is a closed heater?

A. In this form of heater the feed water is subjected to the temperature of the steam by bringing the metal **tubes** through which the feed water is pumped, in contact with the steam. The steam itself does not come in contact with the feed water.

Q. What is an open heater?

A. In this form of heater the **steam** comes in **direct contact** with the feed water, which absorbs the heat of the steam.

Q. What is a coil heater?

A. This is a form of an open heater in which the exhaust steam does not come in direct contact with the feed water, but passes through **coils** of pipe submerged in a suitable vessel, or heater, containing the water.

Q. What are the chief advantages of a closed heater?

A. It permits the water to be handled by the pump when cold, and by not bringing it in contact with the exhaust steam it does not **mingle** with the oil or grease carried over from the engine.

Q. What form of heater is most commonly used?

A. The **open** heater, owing to its simplicity.

Q. What is a feed water purifier?

A. It is a form of a feed water heater in which the feed water is heated by live steam to a sufficiently high temperature to **precipitate** most of the scale forming substances in the water.

Q. What is an **economizer**?

A. It is a form of a feed water heater in which the hot gases are utilized before escaping into the chimney for heating purposes, instead of the **exhaust** or **live steam**, as in other forms of feed water heaters.

Q. What is a steam separator?

A. It is an apparatus designed to **remove** the water, oil, dirt and other impurities from a current of steam.

Q. Into what two classes are separators divided?

A. Into **baffle plate** separators, and **centrifugal** separators.

Q. Upon what principle do all separators depend?

A. Upon **inertia**, the water or oil being much heavier than steam.

Q. What is a steam trap?

A. It is an appliance for removing the water of condensation from steam pipes, separators, and similar apparatus, without the **waste** of **steam**?

Q. Into what two classes are steam traps divided?

A. Into **open** traps, and **closed** traps.

Q. What is an injector or inspirator?

A. It is an apparatus for forcing the feed water into a steam boiler.

Q. What is a **water column**?

A. It is a tube with its ends connected to the steam and water spaces of the boiler, and on which tube the gauge cocks and water glass are connected.

Q. What is the object of a **safety** water column?

A. To **give** warning to those in charge of the boiler in case the water varies above or below the **proper** level?

Q. How is **grate area** usually designated?

A. In square feet.

Q. What is the object of the **bridge wall**?

A. To bring the flame and heated gases in close contact with the heating surface of the boiler.

Q. What is the object of the damper?

A. To keep the steam pressure constant by regulating the draft.

Q. Into what two general classes are mechanical stokers divided?

A. Into overfeed and underfeed stokers.

Q. What is the chief advantage in the use of a mechanical stoker?

A. It avoids the constant opening of the fire doors.

CHAPTER VII.

BOILER MANAGEMENT.

Care of Boilers.—Both the safety and the economical operation of boilers require that every care should be taken of them, and that every precaution be observed in their operation. While a boiler is not handsome in appearance and its operation not clean work, there is no piece of machinery that is as **sensitive** to abuse as the ordinary steam boiler. The principal care of a boiler is the **proper firing** of same, and next in importance is keeping it **clean**. The firing of a boiler is generally regarded as a most simple matter requiring but little skill, and only manual labor. This is a great mistake, for the proper firing of a boiler consists of much more than merely shoveling the coal into the boiler furnace. There are certain requirements which must be observed more or less applicable to all steam boilers, and which requirements can only be learned by study and hard work. The first requirement is the starting of the fire under the cold boiler, and to do this there is both a right and a wrong way. The right way is to start the fire so as to burn **slowly** at first, so that all parts of the boiler and settings may become heated gradually and evenly, permitting the boiler to expand uniformly throughout, thus avoiding all strains and injury to the metal. If on the contrary, a hot fire be made at the start, the upper part of the boiler will be heated to a high temperature before the lower part has been scarcely warmed. This is due to the cold water remaining in contact with the lower plate, thus keeping them cool while the upper part of the boiler, not having the water on one side of the sheet, rapidly becomes heated.

The necessity of keeping water in contact with **one side** of all metal of a boiler which is exposed to the direct heat of the furnace or the heated gases, has already been stated. This is required since iron or steel when heated **above 600** degrees Fahrenheit becomes weaker, and it is therefore necessary to prevent a dangerous increase of the temperature of the metal above that temperature, and this can only be done by keeping the water in contact with the metal.

Cleaning Boilers.—The work of cleaning a boiler consists of first removing the handhole and manhole plates after the boiler has been emptied. The mud and loose scale is then scraped out, and the whole interior of the boiler thoroughly rinsed with a hose. If scale has accumulated on the tubes and other heating surfaces, it must be scraped off before it becomes so thick as to cause the overheating of the metal.

The scale on the plates over the fire and around the braces and stays can usually be removed with a hammer and chisel, but **great care** should be taken not to cut into the metal. The scale on the tubes in horizontal boilers can usually be removed by a chain. To use a chain it is only necessary to wrap it around the tube and pull it back and forth. If the boiler is very badly scaled it will require two men to do this work successfully.

The removal of scale by **mechanical** means should only be done when it is absolutely necessary. Proper precautions should be taken to prevent the formation of scale by the use of proper boiler compounds or water purifiers, such a method not only being more economical, but safer in every way than any mechanical method. In using a boiler compound, first have the feed water analyzed by a reliable chemist and then select a compound especially for that particular quality of feed water;

or what is better, have a compound made up **especially** for the feed water from the analysis.

When Cleaned.—How often a boiler should be cleaned will depend chiefly on the **amount** of water the boiler is evaporating, and upon the **quality** or **purity** of the water.

In some cases a boiler will require cleaning every week, while other boilers must be cleaned once every two weeks, or in many instances only once a month. The **average** time a boiler can be economically operated without being cleaned is about three weeks, and should the boiler be equipped with mechanical cleaners, the time can then be extended to about once every four weeks.

Deterioration.—All boilers are subject to rapid deterioration from the time they are first constructed to their condemnation as unsafe for further use. To avoid such deterioration as much as possible, the exterior of all boilers should be carefully covered so as to protect them from the weather or from any water dripping upon them. When boilers are not in service this deterioration continues, though every precaution is taken against it.

To avoid this as much as possible the boiler should be carefully cleaned, including the furnace, ash pit and combustion chamber, immediately upon being cut out of service. All valves and joints should be made **tight**, and the boiler setting put in good condition. After this is done, to further prepare the boiler for a period of idleness, 40 or 50 pounds of soda should be placed along the bottom of the boiler, and the boiler then **filled** up to the highest water level. All valves and the damper should be closed tight.

Boilers Newly Set.—The greatest care should be taken in heating up newly set boilers. The fire should not be lighted under the boilers for at least **ten days**

after the setting of same, as at least this length of time is required to enable all parts of the mason work to set and harden properly. When the fire is started under a newly set boiler for the first time, it should be a very small one, only sufficient to moderately warm all parts of the brick work. This slow fire should be kept up for at least twenty-four hours and not increased but slightly before the second or third day. **Three full days** should elapse before any steam is raised on the boiler.

When steam is raised for the first time, it should not be allowed to go above 4 or 5 pounds pressure, and the steam should then be sent through all the pipes and through the engine before any attempt is made to put them under pressure.

The **object** of these precautions is to prevent injury from any sudden expansion, the masonry not having hardened and the mortar still being green.

Care of Water Tube Boilers.—The soot and ashes collect on the **exterior** of the tubes in this form of boilers, instead of on the interior of the tubes as in fire tube or shell boilers, and such soot and ashes must be as carefully removed in one case as in the other. In this form of a boiler a blow pipe and hose is used through openings left in the brick work. The scale which collects on the **inside** of the tubes of these boilers, is much more difficult to remove than in fire tube boilers, since such scale cannot be reached by an ordinary scraper, but must be **bored** or **drilled** out. There are a number of contrivances which successfully accomplish this object on the market, but they are all more or less open to the same objection which applies to all mechanical devices for cleaning boilers.

Operation of Boilers.—Before filling the boiler with water a careful examination should be made to see that

nothing has been left inside of it, as it often happens that a tool or piece of oily waste, etc., is overlooked, and which may cause a burnt sheet or other damage to the boiler. The manhole and handhole plates should then be replaced, care being taken to see that the gaskets are in good condition. It is usual to place a mixture of cylinder oil and graphite on the outer surface of the gasket, so that it may be removed without tearing, thus permitting the gasket to be again used. These handhole and manhole plates must be properly replaced and secured in order to prevent leakage. Should such leakage occur, it is rarely that it can be stopped by tightening, and it will therefore necessitate blowing the boiler down before a proper joint can be made.

Water Required.—The boiler should then be filled until the water shows at least half way up in the gauge glass, thus insuring that the water covers all parts of the boiler that are exposed to the action of the fire and hot gases.

Filling the Boiler.—The boiler can be filled from the city mains, provided the pressure is sufficient to fill it to the required height. Should there not be sufficient pressure to do so, it will then be necessary to use a hose, or to fill with a steam or hand pump. While the boiler is filling, means should be provided for the escape of the air contained therein, otherwise the pressure caused from the air on the inside of the boiler will prevent the boiler from filling fast, or may prevent it from being filled to the proper height. It is usual therefore to leave the top gauge cock open, or a manhole plate can be left off while filling, but care should be taken to see that the manhole is properly secured before attempting to raise steam. As air is a poor conductor of heat, the openings left for its escape should not be closed until steam is seen

to issue from them, then they should be at once closed so that the steam pressure can be raised as soon as possible without forcing the fires. As soon as sufficient pressure has been raised, the feed pump or injector should be started to see that they are in proper working order, and then the water glass, gauge cocks and all valves should be tested by opening and closing them.

It must never be **assumed** that they are in good condition, but they must be **known** to be so from actual trial.

Cutting the Boiler into Service.—This is done by **slowly** opening the stop valve with which each boiler should be supplied, thus permitting the steam to flow through the engine and the other mechanism in the plant.

Should this valve be opened too quickly, it will cause a sudden change in the temperature and excessive expansion of the piping, thereby causing a **water hammer** in the piping, and **priming** in the boiler. Where two or more boilers, usually designated as a battery of boilers, are all connected to the same header or steam main, the pressure must first be **equalized** between the different boilers before connecting same, in order to prevent a sudden rush of steam from one boiler to another. The pressure on all the boilers should not vary over 2 pounds before it is safe to connect, or cut in, the different boilers. At all times when the boiler is in use, the water should be maintained at a **constant level**, as any great variation in same, means a variation in the steam pressure which would at once effect the operation of the entire plant. In order to maintain a constant level, the feed water must be regularly supplied. Should the water at any time go out of sight, and the true level not found by opening the lower gauge cock and gauge

glass connections, the fires must be at once **deadened** by throwing fresh coal on the same, or covering with ashes, so that the pressure will fall as low as possible without the introduction of feed water or the stopping of the engine. **Do not touch the safety valve**, nor open any of the valves which may cause a sudden **fluctuation** of the water level in the boiler, as this will bring the water in contact with the highly heated metal, causing a sudden increase of pressure by the rapid evaporation of same. By keeping the engine running the steam can be worked off, thus lowering the pressure. The pump and injector should not be started, as this would force the cold water into the boiler, and against the overheated plates.

When a steam pipe bursts the water level is quickly lowered by the rapid discharge of the steam, therefore the fires must be at once deadened to save the top row of tubes, which will soon become left without water around them and exposed to the heated gases.

The fires must **always** be deadened as quickly as possible in case of any accident causing a sudden release of the steam, such as the melting of a fusible plug, the plug from a stop or blow-off cock blowing out, etc.

In case of all such accidents, the first thing which demands the attention of the engineer or fireman in charge, is the **amount** of water in the boiler and the pressure of the steam.

Regulation of Feed Water.—When the boilers of a battery have been cut into service, the **feed water** for same must next be carefully regulated. Each boiler has its own check valve and feed stop valve, all the boilers being usually supplied from one pump. The quantity of feed water admitted to each boiler is regulated by its own feed stop valve.

When the water gets **low** in any boiler, its feed stop valve must be **opened** wider, and at the same time the feed stop valves on one or more of the other boilers in operation must be **partially closed**, thus forcing the feed water into the boiler or boilers requiring it.

Shutting Down.—Shortly before the time for shutting down for the night, the boiler should be filled to the **top** of the water glass, so as to allow for evaporation, or any leakage during the night. This also insures sufficient water in the morning to permit the blowing out of a portion before raising steam, as should always be done.

The fires should next be banked, and all the steam valves closed **tight**, including the valves at the top and bottom of the gauge glass. The damper should be also closed, but **not tight** as an opening should be left to permit the escape of the gases from the banked fire during the night, up the chimney.

Starting Up.—On entering the boiler room the **first thing** the engineer and fireman should observe, is the **quantity** of water in the boiler. To ascertain this, **both** the water glass and the gauge cocks should be tried. Should the water level not be too low, the banked fires should then be spread over the grates, and the damper regulator opened.

Before the pressure begins to rise, the blow-off cocks should be opened, and the boiler blown down about 3 or 4 inches as shown in the gauge glass. This should be done **every morning**, in order that the boiler may be freed as much as possible of all the impurities in the water that have settled during the night. Only such impurities in the water as are held in **mechanical suspension** can be removed in this way. All the other impuri-

ties being held in **solution**, can only be removed by chemical or other means.

While blowing down a boiler, the blow-off must **never** be left while it is open by the engineer or fireman who is in charge.

The water level in a boiler should never be allowed to fall below the first gauge cock, it being the lowest gauge cock; for when the water gets **below** this point almost all the tubes are left **uncovered** with water.

Priming.—This is simply the water in the boiler boiling over, and being carried into the steam pipes and thence to the engine, where it may cause considerable damage.

The most common causes of priming are:

- (1) Insufficient boiler power.
- (2) Defective design of boiler.
- (3) Water carried too high.
- (4) Irregular firing.
- (5) Sudden opening of stop valve.

The first, or insufficient boiler power, is the most common cause of priming. The **only** remedy is to **increase** the boiler capacity of the plant, or **decrease** the amount of work required of the boiler.

When the water surface of the boiler is too small, the steam escapes from the water with difficulty, and, on account of its velocity, carries with it small particles of water which combine with the condensed steam in the pipes and are carried over into the cylinder of the engine.

Water being practically **incompressible**, when it more than fills the clearance space between the piston and the cylinder head, a broken head, or other damage to the engine, is the result.

By the use of a **separator**, the entrained water which is carried over from the boiler can be prevented to a large extent from reaching the engine, but there is always danger of "flooding," or the separator not being properly drained.

It is evident that the use of a separator cannot stop the cause of priming, but only can **prevent** it to a considerable extent.

Priming can be partially remedied by carrying the water **low** in the boiler, but this not only decreases the efficiency of the boiler, but may also cause a burnt tube or plate.

Foaming.—Unlike priming, foaming is due entirely to the condition of the **water**. The water in a boiler does not lift in foaming, as it does in priming, but simply foams over, due to the dirt or grease contained in it.

While foaming and priming come from entirely different causes, the **resulting damages** are usually the same.

Foaming can best be remedied by using the **surface blow-off**. If there is no surface blow-off, the bottom blow-off should then be used.

The **only** effective remedy is the use of **pure water**.

In Table No. 17 is given the analysis of the water used in different cities, showing their scale-forming ingredients.

WATER, ITS IMPURITIES AND TREATMENT.

Properties.—Water is composed, by volume, of oxygen 1 part, hydrogen 2 parts; or, by weight, 88.9 parts oxygen, 11.1 parts hydrogen. It is slightly compressible at the rate of 1/100 of an inch in 18.10 feet by each 15 pounds per square inch pressure. It has a greater **solvent** power than any other known liquid, and it is due to its

absorbent power that it is rarely found pure or free from foreign substances in solution. Like other liquids, it transmits pressure equally in **all directions**, unchanged and without loss of power. A standard United States gallon of fresh water weighs $8\frac{1}{3}$ pounds and contains 231 cubic inches. A cubic foot weighs $62\frac{1}{2}$ pounds at its greatest density (39.2 degrees Fahrenheit), and contains 1,728 cubic inches, or about $7\frac{1}{2}$ gallons. Under atmospheric pressure it boils at 212 degrees Fahrenheit and freezes at 32 degrees Fahrenheit. When evaporated into steam or frozen into ice, water gives up nearly all it contains in solution, so that steam and ice are practically pure. One cubic foot of water expanded into steam, becomes 1,728 cubic feet at atmospheric pressure.

Impurities.—Water can be freed from substances held in mechanical suspension by **filtration**, but the filter does not remove those chemically combined with it. It is therefore apparent that water may be clear and palatable to the taste, as most spring waters are, and at the same time contain mineral impurities very detrimental for steam purposes. To find the pressure in pounds per square inch of a column of water, multiply the height in feet by .434. Approximately every foot of elevation is equal to one-half pound pressure per square inch. This allows for ordinary friction. The mean pressure of the atmosphere is usually estimated at 14.7 pounds per square inch, so that with a perfect vacuum it will sustain a column of mercury 29.9 inches, or a column of water 33.9 feet high.

All water used for boiler purposes, unless it is rain water collected from roofs, or distilled water, contains more or less **scale-forming** material in solution.

ANALYSIS OF ST. LOUIS WATER.**Made January, 1906.**

Organic and Volatile.....	2.572 Grs. Per. U. S. Gallon.
Sodium Chloride .....	.810 Grs. Per. U. S. Gallon.
Sodium Sulphate .....	.466 Grs. Per. U. S. Gallon.
Calcium Sulphate	4.139 Grs. Per. U. S. Gallon.
Magnesium Carbonate	1.924 Grs. Per. U. S. Gallon.
Magnesium Sulphate.....	a trace.

Total Solids	9.911 Grs. Per. U. S. Gallon.
Free Carbonic Acid.....	1.749 Grs. Per. U. S. Gallon.

This water will give a very hard scale of Calcium Sulphate and Magnesia. It will become corrosive on concentration.

ANALYSIS OF SCALE FROM ST. LOUIS WATER.**Made January, 1906.**

Organic and Volatile.....	5.0 per cent.
Calcium Carbonate	32.7 per cent.
Calcium Sulphate	46.5 per cent.
Silica	14.3 per cent.
Iron Oxide and Alumina.....	1.5 per cent.
Magnesia	a trace.

Physical Characteristics.—Thickness, $\frac{1}{4}$ -inch, 6.4 m.m.

Hardness, very hard.

Structure, crystalline and amorphous.

Directions for the Use of the Standard National Boiler Compound.—As a first application use 20 pounds of compound to each 100 H. P. boiler. This quantity must also be applied whenever and immediately after a boiler has been washed out and filled up with **fresh water**.

• An additional $\frac{3}{4}$ pounds per 100 H. P. must be dissolved every day and pumped into the boiler.

Dissolve the compound in about ten times the quantity of **hot water**.

Open the blow-off every 10 hours for an instant only.

Clean and thoroughly wash out each boiler every 30 days, unless water is very bad, then every two weeks, until nearly all old scale has been removed, then clean boilers every 30 days.

Inspection and Laws Governing Same.—The responsibility for the proper inspection of all boilers and attachments rests upon the engineer in charge, it being one of his most **important duties**.

He should know best the condition of all apparatus in the plant of which he is the engineer, and especially of the boiler as it is under his **constant observation**.

It is the duty of the engineer or fireman to at once remedy any defect which may appear in a boiler or its attachments, and if this cannot be done to report it to his employer, and if it is deemed necessary by him for safety, to **shut down** the plant.

The public safety can alone be secured by all boilers and their attachments being placed in charge of competent engineers and firemen, whose competency have been ascertained and properly certified by proper officials. This is especially true since the introduction of compound engines, with the high boiler pressure necessary for their operation, together with the many other requirements of the modern steam plant.

Every part of a boiler, both external and internal, should be carefully examined and tested at least **once every year** by conscientious and competent officials.

Tests.—There are two principal ways of inspecting a boiler, viz.: by the **hammer test**, and by the **hydrostatic test**.

Hammer Test.—In this inspection of a boiler, a hammer is used with which all the plates, stays and tubes are struck, and their soundness thereby determined. All sound plates and tubes when struck give forth a clear bell-like ring, while those defective give forth a dull, hoarse sound.

The sound from a loose or broken stay is quite different from that of a taut one in good condition, and the difference can soon be distinguished.

Hydrostatic Test.—To inspect a boiler by this test, it is necessary to fill the boiler full of water, and apply a **pressure** by means of a pump, which pressure should be considerably more than the working pressure desired to be carried on the boiler.

While such a test will not reveal **weak places** in the boiler, it will show all **leaks** in the boiler and fittings, and will insure the boiler to safely carry the pressure placed on it when properly operated.

Objections and Precautions.—In using the hydrostatic test, there is danger of **straining** the plates beyond their elasticity should an excess of pressure be placed on the boiler, and thereby permanently injuring same. Therefore, it is necessary that only the pressure **required** for safety, be placed upon the boiler.

Again, all **air** must be allowed to escape from the boiler while it is being filled, as should the boiler **burst** while containing air, it would cause the pieces to be thrown with great force.

The **hammer** test is generally preferred for **old** boilers, and the **hydrostatic** test for **new** boilers. To insure safety, **both** tests should be applied whenever it is deemed advisable by the engineer or inspector.

All the cities and many of the states now have **laws** insuring the thorough inspection of all boilers and their attachments.

St. Louis Ordinance.—The ordinances enacted by the City of St. Louis prescribing the manner of inspection of all boilers in that city and the enforcement of same, has long been taken as a model by different states and cities throughout the country, though many of its provisions now need revision in order to make them applicable to the requirements for safety of modern power plants. These statutes and ordinances are in the main similar to the following section taken from the St. Louis ordinance prescribing the manner of inspection:

Manner of Inspection.—The manner of inspection shall be substantially as follows: The owners of steam boilers and users shall have the option of taking the hammer test or the hydrostatic test; also of electing whether the Inspector of Boilers and Elevators or one of the assistant inspectors, mentioned in this chapter and employed and paid by the insurance companies, shall make such test. If the hammer test be asked for, the examination shall be thorough and searching upon every part of the boiler, both internally and externally, including all fittings and attachments. If the hydrostatic test be asked for, each boiler shall be tested by the hydraulic pressure one-fourth greater than the ordinary working steam pressure used, and the certificate of inspection herein provided shall state the maximum pressure at which any boiler may be worked. In case a defect shall be discovered in any boiler or attachment thereto, the Inspector of Boilers and Elevators shall report the same to the owner or user of said boiler or boilers, and state the facts of the case in writing, giving a description of the particular locality in which each defect may be found, and whether of a dangerous character and necessitating immediate repair. If the Inspector of Boilers and Elevators shall at any time find a boiler which, in

his judgment, is unsafe, after inspecting same, he shall condemn its further use. All boilers to be tested by the hydrostatic pressure shall be filled with water by the owners or users, and they shall furnish the necessary labor required to work and handle the pumps in applying the test. When leaks occur which prevent a successful test, the Inspector of Boilers and Elevators shall make a second test, upon receiving notice that all leaks have been repaired. If, upon making a second test, the boiler or boilers are still defective, he shall for each subsequent test, collect an additional inspection fee, but in no case shall he give a certificate until fully satisfied of the safety of the boiler or boilers. All certificates of inspection shall be for one year and no longer. Any owner or user of any boiler or boilers insured by any steam boiler inspection and insurance company duly authorized to transact business in the State of Missouri, shall, upon his request, have the hydrostatic test applied once annually, without extra charge, by the assistant boiler inspector of such company, as provided in this chapter.

Preparing Boilers for Inspection.—When an internal inspection of a boiler is to be made by an inspector, the engineer should be notified several days in advance, so that he may have ample time in which to prepare both the boiler and himself for the work to be done. The time is usually designated by law, and should not be less than 10 days in advance of inspection.

The fires should be drawn and the boiler permitted to cool down at least 24 hours before the time set for the arrival of the inspector. Just before the inspector enters the boiler, it should be thoroughly rinsed out with clean cold water. The ash and soot should be thoroughly cleaned away from the grates, ash pit and com-

bustion chamber, so that the inspector will have easy access to all parts of the interior of the boiler and settings.

The engineer should render every assistance in his power to the inspector, and, as a rule, be guided by his advice. The instructions of the inspector should be faithfully carried out in every detail for it is an exception to find an incompetent or unworthy inspector.

As the public safety depends to a large extent upon a careful and thorough inspection of a boiler and all its attachments, only competent and conscientious men should be employed for this purpose; and it is to the credit of municipalities and insurance companies that they have always maintained the highest standard required for this work, and have rarely, if ever, allowed mercenary motives to endanger the safety of the public.

Explosions.—While there have been many theories as to the cause of steam boiler explosions, there is but one thing certain, and that is that an **over pressure** of steam is the direct cause of all boiler explosions. This over pressure may be due to any one of many causes, but it is safe to say that so long as the pressure does not exceed the strength of the boiler, that there will be no explosion.

Causes.—Among the reasons why a boiler is unable to bear the working pressure may be named: (1) Defective design as to the amount of pressure the boiler is required to stand. (2) Deterioration, that is, reduction of the strength of the boiler from corrosion, incrustation and wear. (3) Defective workmanship or material. (4) Incompetent attendant.

Defective Design.—The boiler may be insufficient or improperly stayed. The openings for manholes, domes, etc., may not have been properly reinforced, thus

weakening the boiler to such an extent as to make it unsafe for the pressure required. Proper provisions for expansion and contraction of the plates may not have been made in the setting of the boiler. The circulation of the water may be so defective as to cause overheating of the shell and tubes, and excessive incrustation.

Deterioration.—The strength of the boiler may be impaired by corrosion, pitting, grooving and fractures. This corrosion may be both internal and external, and it is the external corrosion of a boiler which is the most dangerous. It must be remembered that the deterioration of a boiler is constant, and that there is no way that it can be prevented. All that can be done is to decrease it as much as possible by careful attention.

While low water in a boiler may cause overheating of the plates, making them soft and weak, it is only the indirect cause of any explosion. It is error to believe that cold water coming in contact with plates overheated even to the extent of becoming red hot, will cause an explosion in itself.

Defects of Workmanship.—Such defects consist of careless punching and riveting, fractured rivet holes, broken rivets, carelessly secured stays and fractured flanges. One of the most serious mistakes made by owners of boilers is the patching the old plates with new ones and failing to remove the old rivets, as the greater expansion and contraction of the new plates, cause a severe local strain.

Defects of material are not easily discovered, as an ordinary inspection will not reveal same.

While the safety of the boiler itself is naturally the first consideration in all types of boilers, with the high class of men who are engaged in the construction of boilers, it might be said that less attention can be paid

to the workmanship of boilers than to the many other requirements for its safety. The American boiler leads all boilers in workmanship and efficiency, and any one who finds it necessary to purchase a boiler, can do so with the assurance that no advantage will be taken of him by any of the leading boiler makers of this country. The safety of the public depends to a large extent upon the honor of the plate manufacturer and of the boiler maker, for however strict and often inspections may be made, it is impossible to discover all hidden defects.

Incompetent Attendant.—The incompetency of the engineer, or the attendant in charge, is the direct cause of many explosions. In steam engineering "A blunder is worse than a crime," for a blunder is usually the result of a lack of care. Unless the safety valve of a boiler is given careful attention it is likely to corrode, and it becomes no longer a safety valve, but an instrument of destruction. Through incompetency, a stop valve is often permitted to be placed **between** the boiler and safety valve. Neglect to open this valve, should it at any time be closed, renders the safety valve useless and deceptive, probably causing an explosion.

Prevention.—More rigid steps for the prevention of boiler explosions daily become more necessary, owing to the high steam pressure necessary for compound engines, and the other requirements of the modern steam plant.

Twenty years ago, 75 pounds of steam pressure was all that was necessary to operate the average steam plant; but this average has been increased to at least 110 pounds to meet the present requirements, and boilers carrying as much as 160 pounds of pressure to the square inch, are no longer uncommon.

The enormous amount of **stored energy** in steam boilers can be seen from Table No. 11.

From this it can be seen that an ordinary return tubular boiler under 75 pounds pressure, has stored within it sufficient energy to blow it over a mile into the air.

To resist this enormous energy stored in boilers, with the ever increasing demand upon them, and the destruction that must follow the sudden release of same, more perfectly constructed boilers and more competent engineers in charge of same, are necessary.

The **responsibility** for the preservation of the public safety from such explosions, rests upon the boiler maker and the steam engineer, and no class of men feel this responsibility more, or endeavor to more faithfully discharge their duty, than the **steam engineer**.

RULES FOR MANAGEMENT AND CARE OF STEAM BOILERS.

Hartford Steam Boiler Inspection and Insurance Co.

1. **Condition of Water.**—The first duty of an engineer, when he enters his boiler room in the morning, is to ascertain, by blowing out water column or trying gauge cocks, how many gauges of water there are in his boilers. **Never start nor unbank the fires until this is done.** Accidents have occurred, and many boilers have been entirely ruined, from neglect of this precaution.

2. **Low Water.**—In case of low water, immediately cover the fire with ashes, or, if no ashes are at hand, use **fresh coal**, and close ash pit doors, and leave fire doors open. If oil or gas is used as fuel, shut off the supply from burners. Don't turn on the feed under any circumstances, nor tamper with or open the safety valve. Let the steam outlets remain as they are.

3. **In Case of Foaming.**—Close throttle, and keep closed long enough to show true level of water. If that

level is sufficiently high, feeding and blowing will usually suffice to correct the evil. In case of violent foaming, caused by dirty water, or change from salt to fresh, or **vice versa**, in addition to the action above stated, check draft, and cover fires with fresh coal, or shut off the supply from burners where oil or gas is used for fuel.

4. Leaks.—When leaks are discovered they should be repaired as soon as possible; if leaking occurs at longitudinal seams, notify the company's inspector at once.

5. Blowing Off.—Clean furnace and bridge wall of all coal and ashes. Allow brick work to cool down for two hours at least before opening blow. A pressure exceeding 20 pounds should not be allowed when boilers are blown out, and where practical to run water out without pressure, the boilers should be cooled down thoroughly before emptying, which will render the washing out of scale and deposit easier.

Generally boilers should be blown down two gauges once or twice a day, and entirely emptied once a week, unless the condition of feed water renders more frequent emptying necessary. When surface blow cocks are used, they should be often opened for a few moments at a time.

6. Filling Up the Boiler.—After blowing down allow the boiler to become cool before filling again. Cold water pumped into hot boilers is very injurious from sudden contraction.

7. Exterior of Boiler.—Care should be taken that no water comes in contact with the exterior of the boiler, either from leaky joints or other causes. Particular care should be taken to keep sheets and parts of boilers exposed to the fire, perfectly clean, also all tubes, flues

and connections well swept. This is particularly necessary where wood or soft coal is used for fuel.

8. Removing Deposit and Sediment.—To prevent danger from overheating, causing distortion or cracking of sheets, and to aid in the economical production of steam, the internal surfaces should be kept free from scale or deposit, and the boiler should be opened frequently for examination and cleaning. The condition of feed water determines the time that may elapse between cleanings.

9. Safety Valves.—Safety valves should be tried daily, as they are liable to become fast in their seats, and useless for the purpose intended.

10. Safety Valve and Pressure Gauge.—Should the gauge at any time indicate the limit of pressure allowed by this company, see that the safety valves are blowing off. In case of difference notify the company's inspector.

11. Gauge Cocks, Glass Gauge.—Keep gauge cocks clear, and in constant use. Glass gauges should not be relied on altogether.

12. Blisters.—When a blister or lamination appears there must be no delay in having it carefully examined, and, if severe, notify the company's inspector.

13. General Care of Boilers and Connections.—Under all circumstances keep the gauges, cocks, etc., clean and in good order, and things generally in and about the engine and boiler room in a neat condition.

14. Getting up Steam.—In preparing to get up steam after boilers have been open or out of service, great care should be exercised in making the man and hand-hole joints. The boilers should be vented through the safety valve or gauge cocks, and water run in until it shows at second gauge. After this is done, fuel may

be placed upon the grate, dampers opened, and fires started. If chimney or stack is cold and does not draw properly, burn some oily waste or light kindlings at the base. Start fires in ample time so it will not be necessary to urge them unduly. When steam issues from the vent, close it and note pressure and behavior of steam gauge while raising steam.

If oil or gas is the fuel used, it is very important that steam be raised slowly; that is, no faster than would be possible with coal as fuel. If this precaution is not observed, serious damage to the boiler is liable to result.

Where a boiler is to be cut in with others already in operation, watch the one recently fired up until pressure is up to that of the other boilers to which it is to be connected; and, when that pressure is attained, open bleeder valves long enough to thoroughly drain all water from the steam pipes, and then open the stop valves very slowly and carefully.

15. Gas or Oil Fuel.—When gas or oil is used as fuel, care should be used in adjusting the burners, so that the flame cannot impinge directly on the heating surface; and the checker-work, where used in such furnaces, should be arranged so that it will not concentrate the flame upon the boiler surfaces.

Suitable peep-holes should be provided for observing the fire surfaces during operation of the boiler.

Before lighting the fire, the greatest caution should be observed to see that the drafts are open for a sufficient length of time to remove the gas that may have accumulated in the setting. Never turn on the fuel supply when starting up, or after snapping out of burner, without first introducing a lighted torch or burning waste into the furnace. Disregard of these precautions is liable to result in a serious accident.

In Fig. 85 is shown a bag or bulge in a boiler sheet, caused by the plate becoming overheated, from oil or waste preventing the water from coming in contact with the plate or sheet; as oil is a poor conductor of heat.

In Fig. 83 is shown a common type of a crude oil burner, and a natural gas burner, used in boiler furnaces.

In Fig. 84 is shown the proper installation of an oil burner under a horizontal boiler.

The burners here shown are the Branch burners and furnace installation.

Total Stored Energy of Steam Boilers.

TYPE.	Area of		Pressure Lbs. Per Sq. Inch.	Rated Power, H. P.	Available Stored Energy in			Max. Hgt. of Projection.	
	Grate Surface	Heat Surface.			Water.	Steam.	Total.	Boiler.	Total.
	Sq. ft.	Sq. ft.			Ft. Lbs.	Ft. Lbs.	Ft. Lbs.	Ft.	Ft.
Plain Cylinder.	15	120	100	10	46,606,200	676,008	47,281,808	18913	5814
Cornish.....	36	730	30	60	57,572,730	709,310	58,260,060	3431	1314
2-flue Cylinder.	31	400	15	35	90,570,050	2,377,357	92,949,407	12243	6076
Plain Tubular.	30	852	75	60	50,008,730	1,022,731	51,031,521	5372	2871
Locomotive	20	1200	125	600	64,452,270	1,706,447	66,218,717	3319	2348
Scotch Marine.	32	768	75	300	71,272,450	1,462,430	72,734,880	2889	1873
Flue & Ret. Tub.	72.5	2524	30	200	90,531,420	1,570,517	92,101,987	1084	921
Water Tube	100	3000	100	250	108,346,670	1,311,377	109,624,283	2030	1626

Table No. 11.

CHAPTER. VIII.

LEADING TYPES OF BOILERS, WITH SPECIFICATIONS.

The Brownell Vertical Boiler.—In Fig 12 is shown one of the best-known types of a submerged tubular boiler. The following fixtures are usually sent with all vertical boilers, the seams being as follows:

Boilers over 36 inches in diameter have shell extended 8 inches to form ash pit, and have flat base plate.

Vertical seams double riveted. All boilers have hand-holes above flue sheet and at bottom of fire box for cleaning out.

Fixtures for the above boilers include base, grates and doors.

Fittings include glass water gauge, gauge cocks, 5-inch steam gauge and siphon, pop safety valve, check valve, stop valve and blowoff valve.

The Kewanee Fire-Box Boiler.—In Fig. 86 is shown the ordinary locomotive type of a **fire-box** boiler. It is advisable to always purchase these boilers with **water fronts** and **dry bottoms**, as the ordinary cast iron front will soon burn out, while the corrosion is objectionable in water bottoms. No **cast iron** lugs, flanges or nozzles should be used, but **steel** required throughout.

WICKES VERTICAL WATER TUBE BOILER.

Construction.—This boiler shown in Fig. 87 consists primarily of two cylinders joined together by straight tubes, which are divided by a fire-brick tile passing through their center into two compartments. The whole



The Kewanee Firebox Boiler.
Fig. 86.

in the rear compartment the "downcomers," since the heat and the water, mingled with steam, rise in the forward tubes, and both the heat and the water, in solid column, descend among and in those forming the rear compartment.

Travel of Heat.—This gives the heat two complete sweeps through the entire length of the boiler and the second sweep from above downward. The heat in its double passage surrounds completely and closely the tubes in both compartments.

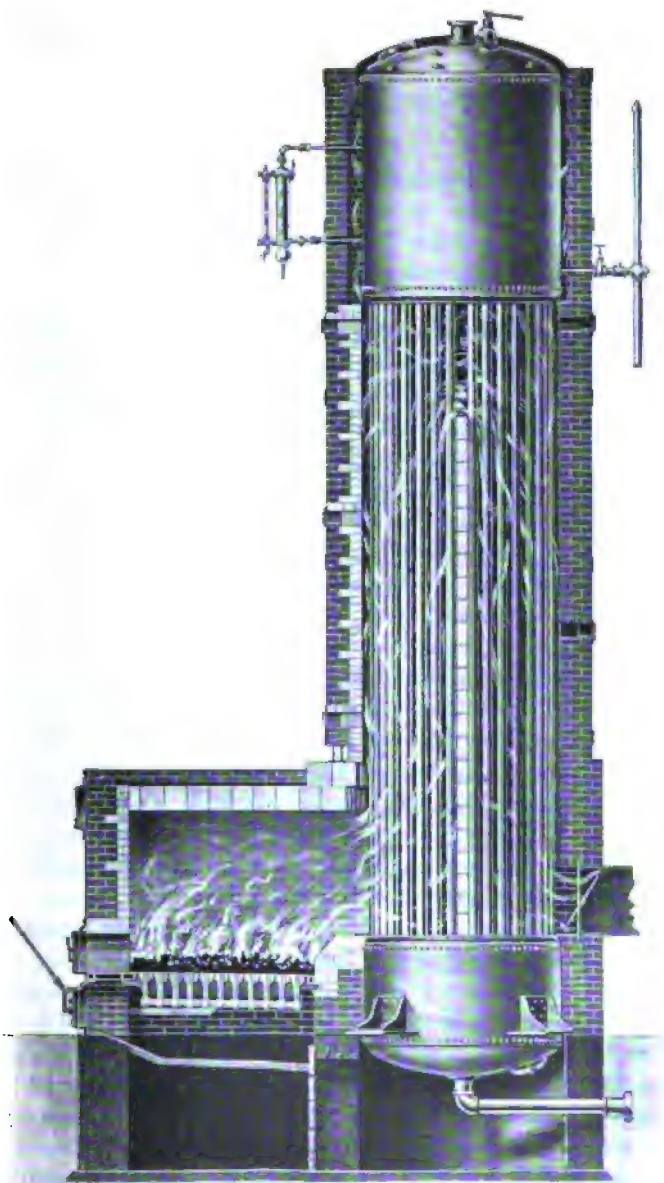
Water Line.—The water line in the boiler is maintained, in the steam drum, at a sufficient height to insure the complete submersion of the tubes.

Baffle Plate.—On a level with the water line, and extending over the tubes in the front compartment, is the baffle plate, which deflects the water of circulation rising, commingled with its steam, directly to the "downcomers," and without splashing and spraying the steam room directly above with globules or masses of water.

Liberating Surface.—Fully two-thirds of the entire area of steam drum is liberating surface, and, as the liberation takes place mainly over the "downcomers," it does so in the quietest manner and in the absence of violent ebullition or turmoil.

Steam Room.—The large steam room is therefore entirely free from water, and the steam outlet is the topmost point, which is far away from the water line, in large boilers the distance being from 6 to 7 feet. On the other hand, the blow-off is at the very lowest point, and where all impurities are precipitated by gravity and by separation due to the flow of the water of circulation.

Feed Water.—The feed water may be introduced in the steam drum directly into the "downcomers" and far



The Wickes Vertical Water Tube Boiler.
Fig. 87.

in the rear compartment the "downcomers," since the heat and the water, mingled with steam, rise in the forward tubes, and both the heat and the water, in solid column, descend among and in those forming the rear compartment.

Travel of Heat.—This gives the heat two complete sweeps through the entire length of the boiler and the second sweep from above downward. The heat in its double passage surrounds completely and closely the tubes in both compartments.

Water Line.—The water line in the boiler is maintained, in the steam drum, at a sufficient height to insure the complete submersion of the tubes.

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Feed Water.—The feed water may be introduced in the steam drum directly into the "downcomers" and far

below the water line, or in the mud drum above the precipitated sediment.

Setting.—The setting of the boiler, which is of brickwork, is arranged so that it is entirely independent of the boiler, and free to expand and contract as its coefficient may dictate, and allow the boiler to expand and contract in accordance with the special laws governing its change of form.

Note how closely confined to the tubes the gases of combustion are after their generation in and leaving the furnace, and how correspondingly absent are the large expansion chambers usually found in boiler settings.

Flow of Heat.—The direct flow of the heat is, by virtue of the draft, over the tile and down by the shortest possible path, or the path of least resistance; while heat of radiation rises naturally and surrounds the steam drum clear to its top, thereby first drying and finally superheating the steam where it leaves the boiler.

Damper.—A single or double wing-damper is placed in the setting at the point of exit of the gases. It is so designed as to allow the quick and easy removal of the wings when cleaning is going on.

Foundation.—The foundation is so designed that by means of a door through the circular brickwork a man can enter underneath the boiler, examine or adjust his blow-off pipe, rivets, and see that the bottom of the mud drum is kept well and heavily painted.

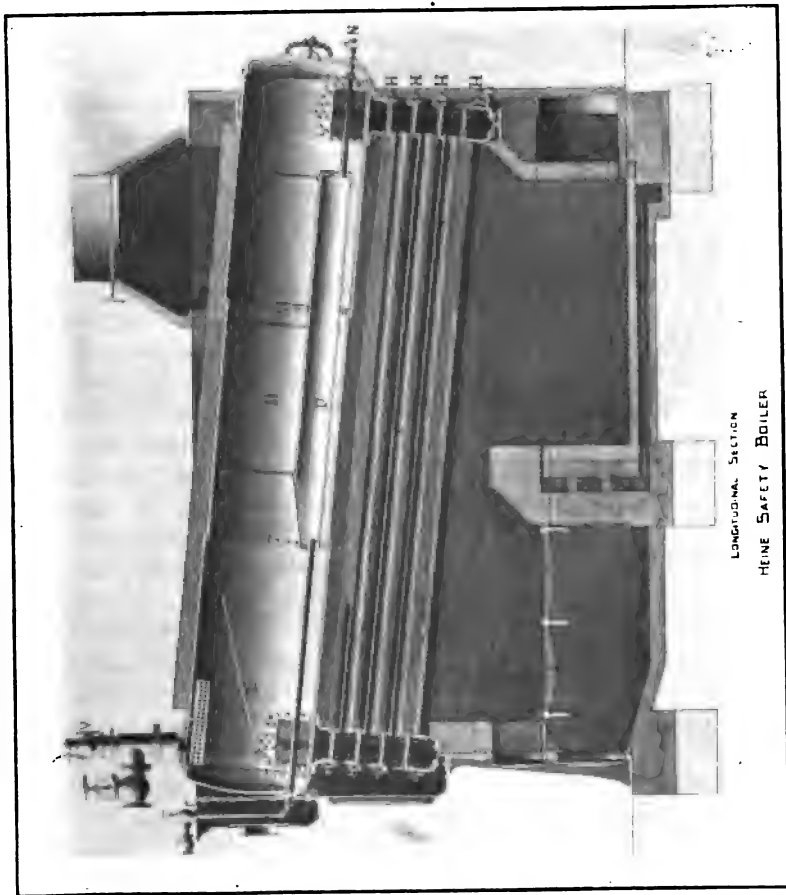
Furnace.—The furnace designed for this boiler is of the "Dutch Oven" type and is built entirely of brickwork. The side walls of this furnace, are made heavy and faced with fire brick, which are laid "headers" around the grate surface. The arch over the furnace is formed of special wedge brick. The weight of the setting is removed from the arch of the furnace by the I

beams shown, and these beams are arranged in box form so placed as to permit a constant flow of air between them, thereby preventing their rise in temperature and consequent expansion.

THE HEINE SAFETY WATER TUBE BOILER.

Construction.—This boiler as shown in Fig. 88 is composed of lap-welded wrought iron tubes, extending between and connecting the inside faces of two “water legs” which form the end connections between these tubes and a combined steam and water drum or “shell,” placed above and parallel with them. (Boilers over 200 horse power have two such shells.) These end chambers are of approximately rectangular shape, drawn in at top to fit the curvature of the shells. Each is composed of a **head plate** and a **tube sheet**, flanged all around and joined at the bottom and sides by a butt strap of same material, strongly riveted to both. The water legs are further stayed by **hollow stay bolts** of hydraulic tubing, of large diameter, so placed that two stays support each tube and handhole and are subjected to only very slight strain. Being made of heavy metal they form the strongest parts of the boiler and its natural supports. The “water legs” are joined to the shell by **flanged and riveted joints** and the drum is cut away at these two points to make connection with inside of water leg, the opening thus made being strengthened by bridges and special stays, so as to preserve the original strength.

The **shells** are cylinders with **heads dished** to form parts of a **true sphere**. The sphere is everywhere as strong as the circle seam of the cylinder, which is well known to be twice as strong as its side seam. There-



The Heine Safety Water Tube Boiler.
Fig. 88.

fore these heads require no stays. Both the cylinder and its spherical heads are therefore **free to follow their natural lines of expansion** when put under pressure. To the bottom of the front head a flange is riveted into which the feed pipe is screwed. This pipe is shown in the cut with **angle valve** and **check valve** attached.

On top of shell near the front end is riveted a **steam nozzle** or saddle, to which is bolted a Tee. This Tee carries the **steam valve** on its branch, which is made to look either to front, rear, right or left; on its top the **safety valve** is placed. The saddle has an area equal to that of stop valve and safety valve combined. The rear head carries a **blow-off flange** of about same size as the feed flange, and a **manhead** curved to fit the head, the manhole supported by a strengthening ring outside. On each side of the shell a square bar, the **tile-bar**, rests loosely in flat hooks riveted to the shell. This bar supports the **side tiles** whose other ends rest on the **side walls**, thus closing in the furnace or flue on top. The top of the tile bar is two inches below **low water line**. The bars rise from front to rear at the rate of 1 inch in 12. When the boiler is set, they must be exactly level, the whole boiler being then on an incline, i. e., with a fall of 1 inch in 12 from front to rear.

It will be noted that this makes the height of the **steam space** in front about **two-thirds** the diameter of the shell, while at the rear the **water** occupies **two-thirds** of the shell, the whole contents of the drum being equally divided between steam and water.

The **tubes** extend through the tube sheets into which they are expanded with roller expanders; opposite the end of each and in the head plates is placed a handhole of slightly larger diameter than the tube and through which it can be withdrawn. These handholes

are closed by small cast iron **handhole plates**, which can be removed in a few seconds to inspect or clean a tube. The cut, Fig. 88, shows these handhole plates marked H. In this cut can be seen the position of these handhole plates, which are held in place by a yoke or crab placed outside to support the bolt and nut. The plates are formed with a shoulder in which is placed the gasket, thereby insuring a tight joint.

Inside of the shell is located the **mud drum D**, placed well below the water line usually paralleled to and 3 inches above the bottom of the shell. It is thus **completely immersed** in the hottest water in the boiler. It is of oval section slightly smaller than the manhole, made of strong sheet iron with cast iron heads. It is entirely enclosed except about 18 inches of its upper portion at the forward end, which is cut away nearly parallel to the water line. Its action will be explained below. The **feed pipe F** enters it through a loose joint in front; the **blow-off pipe N** is screwed tightly into its rear head, and passes by a steam tight joint through the rear head of the shell. Just under the steam nozzle is placed a **dry pan** or **dry pipe A**. A **deflection plate L** extends from the front head of the shell, inclined upwards, to some distance beyond the mouth or throat of the front water leg. It will be noted that the throat of each water leg is large enough to be the practical equivalent of the total tube area, and that just where it joins the shell it increases gradually in width by double the radius of the flange.

Erection and Walling In.—In setting the boiler place its front water leg firmly on a set of strong cast iron columns, bolted and braced together by the door frames, dead-plate, etc., and forming the fire front. This is the fixed end. The rear water leg rests on **rollers** which are free to move on **cast iron plates** firmly

set in the masonry of the low and solid rear wall. Wherever the brickwork closes in to the boiler broad joints are left which are filled in with tow or waste saturated with fireclay, or other refractory but pliable material. Thus **the boiler and its walls** are each **free to move separately** during expansion or contraction, without loosening any joints in the masonry. On the lower, and between the upper tubes, are placed light fire brick tiles. **The lower tier** extends from the front water leg to within a few feet of the rear one, leaving there an upward passage across the rear ends of the tubes for the flame, etc. **The upper tier** closes in to the rear water leg and extends forward to within a few feet of the front one, thus leaving the opening for the gases in front. **The side tiles** extend from side walls to tile bars and close up to the front water leg and front wall, and leave open the final uptake for the waste gases over the back part of the shell, which is here covered above water line with a row lock of **fire brick** resting on the tile bars. The rear wall of the setting and one parallel to it arched over the shell a few feet forward form the uptakes. On these and the rear portion of the side walls is placed a light sheet-iron hood, from which the breeching leads to the chimney. When an iron stack is used, this hood is stiffened by L and T irons so that it becomes a truss **carrying the weight** of such stack and distributing it to the side walls.

Bridge Wall.—The bridge wall is hollow and has small slotted openings in rear to deliver hot air into the half-consumed gases which roll over the bridge wall into the combustion chamber. It receives its air from channels in the hollow side walls (controlled by small cast iron slides), through a cross flue at the rear end and a number of small flues under the floor of the combustion

chamber, as shown in the cut. In the rear wall of the combustion chamber is an arched opening, closed by a cast iron door, which in turn is shielded by a dry fire brick wall easily removable. For special fuels, for smoke prevention, etc., there are now to be had various forms of furnaces, automatic stokers, rocking grate bars, etc.

Circulation.—The circulation, at first slow, **increases in speed** as soon as steam begins to form. Then the speed with which the mingled current of steam and water rises in the forward water leg will depend on the difference in weight of this mixture, and the solid and slightly colder water falling down the rear water leg. The maximum velocity will be reached when the mixture is about half steam and half water. As the area of the throat of the water leg is **practically equivalent** to the **aggregate tube area** (offsetting the greater amount of skin friction in the tubes against the reduced area of the throat), there will be nothing to interfere with the **free action of gravity and the full speed will be maintained** as long as steam is being made. This circulation must be well borne in mind. It is forward through the tubes, upward through the front water leg, to the rear in the shell, and down through the rear water leg. At the forward throat of the shell the channel slightly enlarges by reason of two outward flanges of the water leg. The deflection plate L assists in directing the circulation of the water to the rear. Thus the steam bubbles obtain a trend towards the rear, throwing the spray in a direction away from the flow of steam. It also has the effect of **increasing the liberating surface**. For each section of this moving surface of water, as it is delivering its load of steam, sweeps rapidly to the rear, mak-

ing room for the next section, thus constantly presenting a fresh surface for this work.

The shallowness of the water at the front of the shell makes it easier for the steam to pass through; its depth at the rear ensures a **solid body of water** for replenishing the rear water leg and tubes. The height of the steam space in front removes the nozzle far out of reach of any spray; the deflection plate catches and deflects any sudden spurt, while finally the dry pan or dry pipe draws the steam from a large area, from three sides, **thus preventing any local disturbance.**

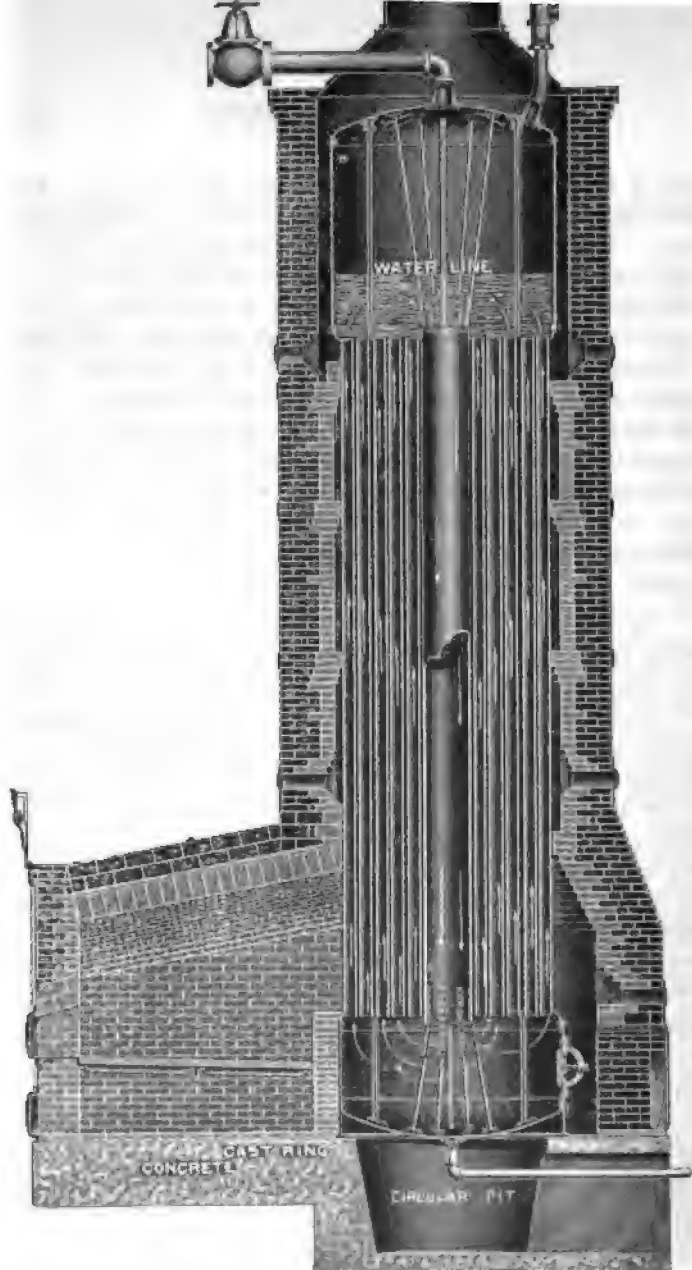
The action of the **mud drum** is as follows: The feed water enters it through the pipe F about $\frac{1}{2}$ -inch above its bottom; even if it has previously passed the best heaters it is colder than the water in the boiler. Hence it drops to the bottom, and, impelled by the pump or injector, passes at a **greatly reduced speed** to the rear of the mud drum. As it is gradually heated to near boiler temperature it rises and flows slowly in reverse direction to the open front of the mud drum; here it passes over in a **thin sheet** and is immediately swept backward into the main body of water by the swift circulation, thus becoming **thoroughly mixed** with it before it reaches the tubes. During this process the mud, lime salts and other precipitates are deposited as a sort of semi-fluid "sludge" near the rear end of the mud drum, whence it is blown off at frequent intervals through the blow-off valve.

Cleaning.—This explanation of the action of the mud drum shows how **the inside of the tubes may be kept clean.** To keep the **outside clear of soot and ashes** which deposit on, and sometimes even bake fast to the tubes, each boiler is provided with two special nozzles with both side and front outlets, a short one for the

rear, a long one for the front. They are of $\frac{3}{4}$ -inch gas pipe and each is supplied with steam by a $\frac{1}{2}$ -inch steam hose. The nozzle is passed through each stay bolt in turn, and thus delivers its side jets on the three or four tubes adjacent, with the full force of the steam, at the short range of two inches, **knocking the soot and ashes** off completely, while the end jet carries them into the main draft current to lodge at points in breeching or chimney base convenient for their ultimate removal. An inspection of the cuts will show that the stay bolts are so located that the nozzle can in turn be brought to bear on all sides of the tubes. As soon as the nozzle is withdrawn from the stay bolt, this is closed air-tight by a plain wooden plug.

In cleaning a boiler it is only necessary to **remove every fourth or fifth handhole plate** in the front water leg; the water hose, supplied with a short nozzle, can be entered in all the adjacent tubes, owing to the ample dimensions of the water leg. In the rear water leg only one or two handholes in the lower row need be opened to let the water and debris escape. A lamp or candle hung on a wire through the manhead may be held opposite each tube so that it can be perfectly inspected from the front. Once or twice a year, where **the water is very scale bearing**, it may be advisable to take off all the handhole plates of the front water leg and pass a scraper through all the tubes in succession. The ashes which deposit in the combustion chamber are removed through the ash pit door in the rear wall, never allowing it to become more than one-third full.

The Cook Water Tube Boiler.—In Fig. 89 is shown the construction of this boiler, which is extremely simple, consisting essentially of two steel cylinders, connected together by a large number of 4-inch lap welded boiler



The Cook Water Tube Boiler.
Fig. 89.

tubes, the ends of which are expanded into the end of the drums.

THE CAHALL VERTICAL WATER TUBE BOILER.

Construction.—This boiler, as shown in Fig. 90, consists of two drums arranged one above the other, made of best mild open hearth flange steel, and connected with 4-inch lap-welded best charcoal iron tubes. These tubes are vertical, are perfectly straight throughout their entire length, and are expanded into the drums at each end.

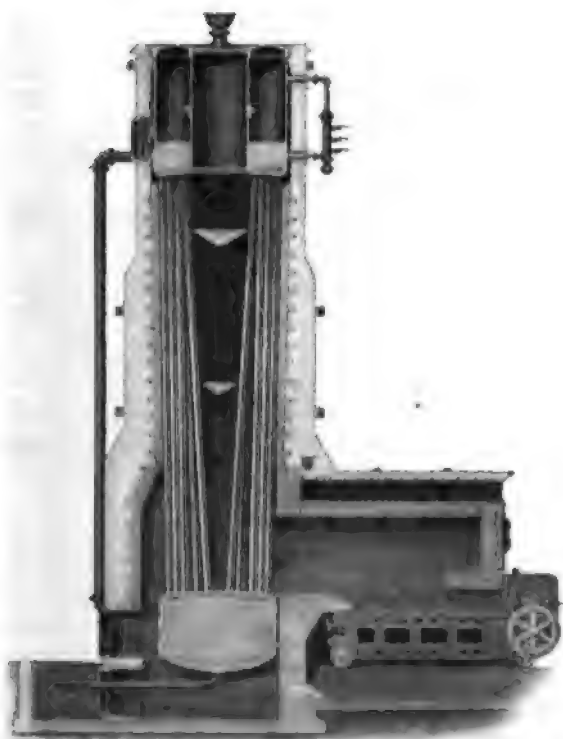
The upper or steam drum has an opening through its center for the exit of waste gases. These gases, although reduced to a very low temperature in passing through the closely grouped tubes of the boiler, will impart most of their retained surplus heat to the metal sides of the passage through this upper drum, thereby tending to slightly superheat the steam in the chamber above. The water line in the upper drum is about 2 feet above the bottom of the drum, the drum itself being about 7 feet high in the clear inside, leaving a space of 5 feet between the surface of the water and the point at which the steam is drawn off from the boilers, which prevents the carrying over of water with the steam, either in the form of supersaturation or mechanical entrainment.

An external circulating pipe comes out from the upper or steam drum, just below the water level, and is carried downward, outside the brickwork, to a point just below the tube sheet of the lower drum, where it enters that drum. There being no steam whatever in this external circulating pipe, and no possibility of mak-

ing any, and there being, in the tubes connecting the two drums, steam in greater or less proportions, the result is (the volume in the external pipe having a considerably greater specific gravity than the mixture of steam and water in the tubes) a very rapid, positive circulation in one direction; the water in the tubes connecting the drums ascending to the steam drum, delivers this mixture of water and steam there, whereupon the steam separates from the water, and after traveling the space of 5 feet from the water level to the top of the drum, escapes, and the water which is left behind enters the circulating pipe and is carried down to the mud drum and again arises with its mixture of steam.

The boiler rests upon four iron brackets riveted to lower, or mud drum, supported upon four piers of the foundation, the entire structure standing without contact with the brickwork, allowing the boiler freedom for expansion without in any way straining the brick setting. In all places where pipe connections are made to the boilers through the walls, they are encased in expansion boxes.

Owing to the fact that the gases escape through the central opening in the upper drum, the upper tube sheet has a circular opening in its center, leaving a central open space between the tubes, which gradually narrows to the bottom tube sheet. Advantage is taken of this space, which is in the form of an inverted cone, to introduce deflecting plates, which in connection with corresponding baffles or offsets in the brick casing cause the gases to be alternately thrown out and in throughout the whole heating surface, which extracts from these gases their heat, until they come to very nearly the temperature of the water contained in the boiler.



The Cahall Vertical Water Tube Boiler.

Fig. 90.

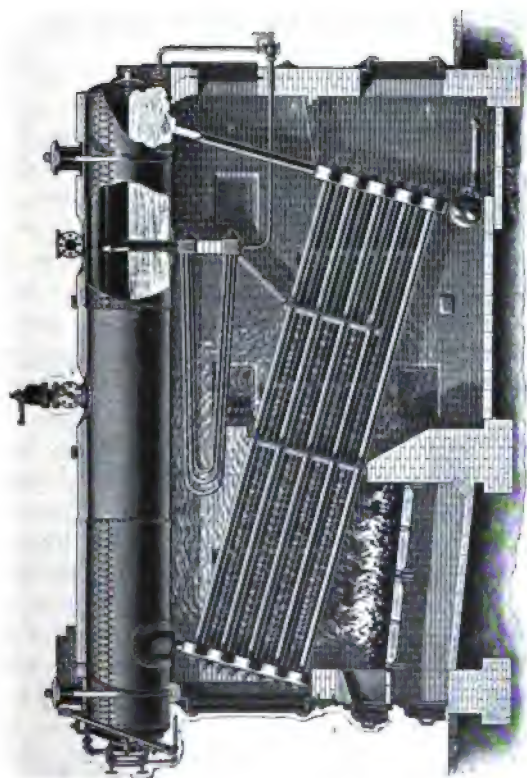
THE BABCOCK AND WILCOX WATER TUBE BOILER.

Construction.—This boiler as shown in Fig. 91 is composed of lap-welded wrought iron tubes, placed in an inclined position and connected with each other, and with a horizontal steam and water drum, by vertical passages at each end, while a mud drum is connected to the rear and lowest point in the boiler.

The end connections are in one piece for each vertical row of tubes, and are of such form that the tubes are "staggered" (or so placed that each row comes over the spaces in the previous row). The holes are accurately sized, made tapering, and the tubes fixed therein by an expander. The sections thus formed are connected with the drum, and with the mud drum also by short tubes expanded into bored holes, doing away with all bolts, and leaving a clear passage way between the several parts. The openings for cleaning opposite the end of each tube are closed by handhole plates, the joints of which are made in the most thorough manner, by milling the surfaces to accurate metallic contact, and are held in place by wrought iron forged clamps and bolts. They are tested and made tight under a hydrostatic pressure of 300 pounds per square inch, iron to iron, and without rubber packing, or other perishable substances.

The steam and water drums are made of flange iron or steel, of extra thickness, and double riveted. The mud drums are of cast iron, as the best material to withstand corrosion, and are provided with ample means for cleaning.

Erection.—In erecting this boiler, it is suspended entirely independent of the brickwork, from wrought iron girders resting on iron columns. This avoids any straining of the boiler from unequal expansion between it and



The Babcock and Wilcox Water Tube Boiler.
Fig. 91.

its enclosing walls, and permits the brickwork to be repaired or removed, if necessary, without in any way disturbing the boiler.

THE STIRLING WATER TUBE BOILER.

The Stirling Boiler (Figs. 15 and 54) consist of three upper or steam drums, each connected by a number of tubes (called a "bank") to a lower or mud drum. Suitably disposed firetile baffles between the banks direct the gases into their proper course. Shorter tubes connect the steam spaces of all upper drums, also water spaces of front and middle drums. The boiler is supported on a structural steel frame work, around which is built a brick setting whose only office is to provide furnace space, and serve as a housing to confine the heat.

The Drums vary from 36 to 54 inches in diameter and are made of the best open hearth flange steel. The plates extend the entire distance between heads, hence there are **no circular seams**. The longitudinal seams—which are double or triple riveted according to the working pressure to be carried—are so placed that they are not exposed to high temperature. The drum heads are hydraulically dished to proper radius; each drum is provided with one manhole, and the manhole plate and arch bars are of wrought steel; four manhole plates, which can be removed in a few minutes, give access to the entire interior of the boiler, and expose every tube end, rivet, and joint. The drum interiors are perfectly clear; there are no baffles, stays, tie rods, mud pipes, or other obstructions in them.

The tubes are lap-welded mild steel. They are slightly curved at the ends to permit them to enter the drums normally and to provide for free expansion of the boiler when at work. The tubes are expanded di-

rectly into reamed holes in tube sheets of the drums. Every tube end is visible and accessible.

Steel Framework.—As the entire weight of boiler and contents is supported on the steel framework, cracking of the setting due to unequal settlements is obviated, and no blocking is needed when the brickwork has to be repaired.

Baffles and Course of Gases.—The baffle walls rest directly upon the tubes, and guide the course of the gases up to the front bank, down the middle and up the rear bank, thus bringing them into such intimate contact with the boiler surface that the heat is quickly and thoroughly extracted from them. The baffles are made of plain rectangular firetile.

Rapid Circulation.—The path of the circulation in the Stirling is as follows: The water is fed into upper rear drum, passes down the rear bank of tubes to the lower drum, thence up the front bank to forward steam drum. Here the steam formed during passage up the front bank disengages and passes through the upper row of cross tubes into the middle drum, while the **solid water** passes through the lower cross tubes into middle drum, then down the middle bank to lower drum, from which it is again drawn up the front bank to retrace its former course until it is finally evaporated. The steam generated in the rear bank passes through cross tubes to the center drum.

The temperature of gases in contact with the tubes will evidently be greatest at the bottom of the front bank, and gradually decrease as the gases proceed along their course to the breeching. Obviously then the velocity of water circulation and quantity of steam generated will be a maximum in the front bank; in the rear bank there is a slow circulation downward equal to the quantity of water evaporated in the other two banks.



The Brownell Internally Fired Boiler.
Fig. 92.

SPECIFICATIONS FOR A 20 HORSE POWER VERTICAL SUBMERGER FLUE BOILER.

This boiler shall be built in accordance with the following specifications:

Dimensions:

- Diameter of boiler, 42 inches.
- Height of boiler, 96 inches.
- Height of fire box, 30 inches.
- Number of tubes, 85.
- Diameter of tubes, 2 inches.
- Length of tubes, 48 inches.
- Thickness of shell, $\frac{1}{4}$ inch.
- Thickness of fire box, $\frac{5}{16}$ inch.
- Thickness of heads, $\frac{3}{8}$ inch.
- Thickness of cone, $\frac{5}{16}$ inch.
- Diameter of rivets, $\frac{11}{16}$ inch.
- Diameter of rivet holes, $\frac{3}{4}$ inch.
- Pitch of rivets, 1 inch.

Steel Plates.—All plates used in the construction of the boiler shall be of the best open hearth steel having a tensile strength of from 55,000 to 60,000 pounds per square inch of section, to show an elongation of not less than 25 per cent in a parallel test piece 8 inches long, accompanied by a reduction in area of not less than 50 per cent and to endure a bending of 180 degrees flat upon itself without fracture, both before and after being brought to a red heat and quenched.

The maker's name, brand and tensile strength to be stamped on each sheet, and plainly visible for inspection.

Fittings.—This boiler is to be equipped with a full set of fixtures and fittings, which includes base, grates, doors, glass water gauge, steam gauge and siphon, gauge

cocks, safety valve, check valve, stop valve, blow-off valve and smoke stack. Boiler to have hand holes above flue sheet and at bottom of fire box for cleaning out.

SPECIFICATIONS FOR A 25 HORSE POWER LOCOMOTIVE TYPE OF BOILER.

The contractor will furnish and deliver at one horizontal portable, water front, open bottom steam boiler of 25 horse power capacity at 100 pounds working pressure in accordance with these specifications.

Workmanship.—The material used in the construction of this completed apparatus shall be new and unused and the best of their respective kinds when not otherwise specifically mentioned. This boiler shall be not less than 25 horse power and not less than the following dimensions:

Dimensions:

Diameter in inches, 36 inches.
Length of fire box, 52 inches.
Height of fire box, 38 inches.
Width of fire box, 30 inches.
No. of 3-inch tubes, 34.
Length of tubes in inches, 96 inches.
Thickness of shell, $\frac{1}{4}$ inch.
Thickness of outside of fire box, $\frac{5}{16}$ inch.
Thickness of furnace plate, $\frac{5}{16}$ inch.
Thickness of tube sheets and heads, $\frac{3}{8}$ inch.
Size of dome, 18x18 inches.
Size of safety valve, 2 inches.
Size of blow-off, $\frac{1}{4}$ inch.
Size of check and stop valve, 1 inch.
Diameter of stack, 18 inches.

Steel Plates.—All plates and heads used in the construction of this boiler shall be of the best quality of open hearth steel having a tensile strength of from 55,000 to 60,000 pounds per square inch of section, to show an elongation of not less than 25 per cent in a parallel test piece 8 inches long, accompanied by a reduction in area of not less than 50 per cent, and to endure bending 180 degrees flat upon itself without fracture both before and after being brought to a red heat and quenched.

The maker's name, brand and tensile strength to be stamped on each sheet and plainly visible for inspection.

Fittings.—This boiler is to be equipped with a full set of fixture and fittings including injector and smoke stack hinged complete, ready for steaming, also set of firing tools. The contractor shall also furnish a certificate of inspection from any good insurance company, and also from the Inspector of Boilers and Elevators of

Running Gear.—This boiler shall be mounted on running gear with iron wheels, single and double trees and tongue well built and substantially the same as shown on drawings accompanying these specifications.

SPECIFICATIONS FOR A HORIZONTAL RETURN TUBULAR BOILER WITH DOWN DRAFT FURNACE.

1. **Number and Type.**—There will be one boiler of the horizontal return tubular pattern, 66 inches diameter, 18 feet long. Thickness of shell, $\frac{3}{8}$ inch; heads, $\frac{1}{2}$ inch. Shell to be built of two plates, each forming a complete ring. Longitudinal seams well removed from the fire, and alternated to avoid a continuous line. A smoke box extension extending above tubes will be

bolted to the front end, to be of steel, 18 inches long, .134 inch thick (No. 10 B. W. G.).

2. Dome.—Shell to have steam dome as shown, 36 inches diameter, 36 inches high, measured on side. To have bumped head. Material, steel, 5-16 inch thick. Shell to be well reinforced under dome, and to have three 3-inch openings through shell for steam supply, and two $\frac{1}{4}$ -inch drain openings.

3. Steel Plates.—Shells, heads, and domes to be made of flange steel, having an ultimate tensile strength of not less than 60,000 nor more than 65,000 pounds per square inch elastic limit one-half the ultimate; elongation in 8 inches not less than 27 per cent; maximum phosphorus, 0.06 per cent; maximum sulphur, 0.04 per cent. The material is to stand bending double on itself without fracture, both cold and after being brought to a flanging heat and quenched with water of 70 degrees temperature. Plates to be free from surface defects, of homogeneous and uniform quality and thickness, of workmanlike finish, and stamped with the maker's name and tensile strength. These stamps are to be preserved for identification, and are to be so placed as to be visible from outside of boiler. Edges of plates to be planed to proper bevel.

4. Riveting Etc.—Longitudinal seams to be triple riveted butt joints of at least 87.5 per cent efficiency with inner and outer covering straps. Girth seams single riveted. Vertical and base seams of dome double lap riveted. Rivets to be of good charcoal iron, or of extra soft steel, of 52,000 to 62,000 pounds tensile strength and 38,000 pounds shearing strength. They are to be capable of bending double on themselves, without fracture, both cold and after being heated to cherry red and quenched. They will have hemi-spherical or conical

heads, and be of sufficient length to make the formed heads equal in strength to the pressed heads, and must fill the rivet holes completely. Heads to be concentric with rivets. Rivet holes to be punched $3/32$ -inch small and then reamed out. Both before and after sheets are assembled the burrs and sharp edges of rivet holes are to be removed by reaming and countersinking. The improper use of the drift pin is prohibited. Defective riveting must be promptly cut out and satisfactorily replaced. The design of seams, dimensions of rivets, pitch, spacing, and lap, as well as other details not specifically described herein, are to be in accordance with the best engineering practice.

5. Bracing.—Heads to be well stayed by a sufficient number of McGregor, Lukens, or Huston crow foot braces, made of single pieces of open hearth homogeneous flange plate, bent to shape in one heat without weld, and then annealed.

6. Tubes.—Boiler to have 72 tubes, $3\frac{1}{2}$ -inch external diameter, 18 feet long, not less than .12 inches thick (No. 11 B. W. G.), accurately and uniformly spaced, and neatly expanded into heads. Copper ferrules to be used in rear heads. Tubes to be of best soft steel, lap welded or drawn, and ends annealed before setting. The tube holes are either to be drilled or punched out, and then neatly reamed. Corners to be chamfered off, and heads annealed after punching and before reaming.

7. Working Pressure.—The boiler is intended to work regularly at approximately 115 pounds. With furnace attached, the boiler will be tested by the contractor after erection, in the presence of the engineer, under 175 pounds hydrostatic pressure, and be made tight under same. All parts to be proportioned for a

factor of safety of not less than five on minimum sections.

8. Flanges and Caulking.—All flanges are to be turned at a good red heat, to radii of not less than 2 inches, and must be free from hammer marks and other flaws. All plates to be annealed after flanging. The caulking is to be done in best manner, with round nose tools. All accessible seams to be caulked on both sides.

9. Man-Holes.—There will be two man-holes in each shell, 10x16 inches or 11x14 inches, one in rear head above tubes, or in top of shell, and the other in front head under tubes. They will be of the Eclipse pattern, or its equivalent, complete with grooved lids, pressed steel arches, bolts, nuts, and grooved lead gaskets.

10. Openings.—The boiler will have one 5-inch opening on side of dome for main steam outlet; one 3½-inch for safety valve; two 1¼-inch for water column; one 1½-inch for feed; one 2-inch for auxiliary steam service; one 3-inch for gravity return and blow-off. The 5 and 3½-inch openings to have cast or pressed steel nozzles well riveted to shells, with flanges properly finished, the former for a standard 5-inch pipe flange, and the latter for flange of safety valve. Two and 3-inch openings to be reinforced by flanges, well riveted and threaded.

11. Fittings and Fixtures.—Furnish with boiler: One 3½-inch nickel seated flanged pop safety valve, set to blow at 115 pounds, one 1½-inch check valve, one 1½-inch stop valve, one 2-inch Homestead or equivalent blow-off cock, connected to 3-inch line by reducing T. Other valves to be of approved make, and all to be of best composition steam metal. One bronze mounted water column, not less than 4-inch internal diameter,

with 1¼-inch unvalved connection to shell, made up with tees, crosses, and plugs, to permit cleaning. To be complete with necessary valves, guards, and three try cocks. Valves and cocks to be operated from floor level by chains. One 8-inch dial, brass case, steam gauge, reading to 200 pounds, with syphon of approved form, drain and coupling. Attach 1½-inch feed pipe 16 feet long to front head inside of boiler, with elbow looking downward at rear end, properly supported. Front end to have T with one end closed by brass plug. Furnish all pipe and fittings necessary, and connect above named valves and fittings to boiler. Provide side and rear angles shown on plans for brick work joints, and attach same rigidly to boilers. Furnish additional angle, as shown, for rear arch support for brick mason, with anchor bolts, to go through rear wall.

12. Casting, Etc.—Provide one ornamental full flush front with suitable doors, opening to right and left. Fire and ash doors to be fastened with independent frames, bolted on, and to have registers. Fire doors of Pickle or equivalent pattern. Provide all necessary liners, plates, arches, jambs, rods, nuts, washers, and floor plates. Front to be lettered:

.....

Furnish one clean out door, with frame, complete, with register, or peep hole. All doors to be close fitting and air tight. Furnish stack plate for chimney, with close fitting swing damper and handle, counterweighted and provide with chain and hook plate located on front near fire doors. Furnish skeleton arches for fire brick at rear-head. Furnish two 10 foot wall binding bars with rods, plates, washers, and nuts, as required by plan. Castings to be smooth, close grained, sound, tough, of

true forms and dimensions, free from blow holes, flaws, scabs, and other defects.

13. Furnace.—Provide boiler with an approved form of down draft furnace. The front will have fire doors opening across full width of furnace, to be of the Pickle, or equivalent pattern. Upper grates $4\frac{1}{2}$ feet long, to consist of a single row of $2\frac{1}{2}$ -inch special high grade steel tubing. Front drum 10 inches diameter, of high grade steel tubing with hand-hole; rear drum 20 inches diameter, of fire box steel, with man-hole complete. Provide all necessary circulating pipes, blow-offs, and valves. Lower grates 5 feet long, of the ordinary pattern, with bearing plates. Fittings, steel.

14. Deflectors.—Front head to be provided with hinged removable deflecting dampers over upper rows of tubes, as shown on plan. These dampers to be made of $\frac{3}{16}$ -inch steel, with extension at top of each end, supported in $\frac{1}{2}$ -inch holes in smoke box extension on both sides.

15. Smoke Flue.—Furnish and erect one smoke flue, of dimensions and shape shown on plan. Material, sheet steel, .134-inch thick (No. 10 B. W. G.). Front end shaped to fit stack plate, rear end to fit entrance into brick chimney base. Provide suitable hanger to support flue near its center.

16. Supports.—The boiler will be hung from four steel channels each 10 inches deep, weighing not less than 15 pounds per foot, and of full length, resting on steel columns. Side lugs to be of steel plate carefully shaped and well riveted to shell. Each lug to be drilled accurately and in line to receive the supporting links, which—with channels, links, columns, plates, nuts, and washers—are to be furnished by this contractor, as detailed on plans.

17. Painting.—The boiler, supports, smoke flue, fire front, fire, ash and cleaning doors, and other metallic parts—except grates—shall, after being cleaned and inspected, receive one coat good black asphaltum, before shipment, and another after erection and completion.

18. Foundation.—To be of dimensions shown on plans, of concrete made of approved Portland cement, mixed one part cement to three of clean sharp river sand, and worked up with five parts clean crushed macadam, of sizes that will pass through a 1½-inch ring, and well wetted. When dumped pack down thoroughly with a heavy maul, until the water works to the surface. Ash pit under and in front of boiler to have good granitoid flooring. Cut and repair present boiler room floor as may be necessary, including new cement pit in front of boiler, as shown on plan.

19. Brick Work.—Furnace walls to be of hard red brick, carried up together, plumb, straight, and level. Facing of selected smooth hard red brick. Cover top of shell with brick on edge, well plastered. Every fifth course headers. Carry up smoke outlet ready to receive stack plate. Wall in all necessary rods, plates, doors, frames, etc. Joints to be flushed full, and neatly trowelled. Mortar to be of good sharp sand and fresh lime, one barrel Portland cement added for every four thousand brick. All walls to have air spaces. Cut and repair brick work in south face of chimney to receive smoke flue. Move present clean out door in base of chimney to south face, with necessary brick work.

20. Fire Brick.—All parts of the furnace exposed to the flame to be lined with good St. Louis fire brick, dipped in dry milled fire clay, and laid with very thin joints. Headers every fifth course. All brick in front

faces of bridge walls to be headers. Use jamb, wedge or other shaped brick wherever directed.

21. Erection.—This contractor will deliver all material herein provided for in, and will erect same in position ready for external pipe connections. He will place in permanent position, ready for use, all foundations, brick work, fixtures, fittings, etc., belonging to the boiler. He will take all necessary measurements and verify all data on the ground.

22. Inspection and Insurance.—The contractor will furnish the purchaser with a Certificate of Inspection and Policy of Insurance for \$500.00 for one year, in some good insurance company. The contractor will arrange for all necessary tests, inspections, etc., required by said insurance company, and by the ordinances of the City of, and will deliver to the purchaser, without extra charge, certificates of such tests, etc., authorizing the purchaser to operate the boiler under the desired conditions.

SPECIFICATIONS FOR A 100 HORSE POWER WATER TUBE BOILER, INCLUDING SPECI- FICATIONS FOR A DOWN DRAFT FURNACE AND SMOKE STACK.

Number, Type and Size.—There shall be one boiler of the horizontal inclined water tube type, rated at 100 horse power; the term horse power being understood to mean 30 pounds of water evaporated per hour from feed-water having a temperature of 100 degrees Fahrenheit into steam at 70 pounds gauge pressure.

General Description.—The boiler in all its main parts is to be composed of plate steel. It is to consist of two water legs of equal size, approximately rectangu-

lar in shape, joined together by means of a series of vertical and horizontal staggered rows of tubes, and one overhead circulating steam and water drum... The drum... and tubes are to be made parallel to each other, and the water legs made perpendicular to both. When boiler is erected, same must incline towards the rear a distance of 1-inch per lineal foot.

Plates.—All plates used in the construction of this boiler are to be of the best open hearth homogeneous flange steel, having a tensile strength of 60,000 pounds per square inch of section. These plates are to be plainly stamped with the name of the manufacturer, the tensile strength and the quality; said stamps to be so located as to be easily visible after the boiler has been completed.

The thicknesses required for these plates are given under the various paragraphs relating to the specific parts of the boiler herein described.

Tubes.—This boiler is to contain sixty-one (61) tubes, each having an outside diameter of $3\frac{1}{2}$ inches, and a length of 16 feet. Each tube is to be of the best lap-welded quality, standard gauge in thickness, and made of steel. The ends of all tubes are to be thoroughly expanded into the tube plates of the water legs.

The distance from center to center horizontally of the tubes is to be $7\frac{1}{4}$ inches, and the distance vertically is to be 5 inches, except that between the bottom row and the next row above, which is to be $8\frac{1}{2}$ inches, so as to permit the introduction of a course of tile on top of the lower row. The boiler is to be made eight rows wide and eight rows high.

Water Legs.—This boiler is to be furnished with two water legs, each consisting of a tube plate, and a hand hole plate joined together by means of a strap riv-

eted around the outside. These plates are to be so arranged as to leave a clear space of 10 inches between them on the inside.

The hand hole plate of each water leg is to be furnished with a series of oval hand holes, each measuring $3\frac{5}{8}$ inches in size, and furnished with a heavy cast iron cover plate, one arch, one bolt and a lead gasket. A hand hole is located directly in front of each end of each tube so as to permit easy access for cleaning.

The water leg plates are to be thoroughly stay-bolted together by means of hollow stays, each having a minimum outside diameter of $1\frac{9}{16}$ inches, spaced a distance of $7\frac{1}{4}$ inches center to center horizontally, 5 inches center to center vertically.

All seams around the perimeters of the water legs are to be furnished with single riveted lap joints with rivets spaced a distance of 2 inches center to center, and having a diameter, after being driven, of $13/16$ inch. At the throats where the legs are attached to the circulating drums, double riveted lap joints are used.

Circulating Drum.—This boiler to be furnished with one drum for permitting the circulation of the water from the front water leg to the rear water leg, and also affording a steam space in the upper half. This drum is to have an internal diameter of 36 inches, and a length of shell of 19 feet 3 inches. The heads of this drum are to be dished to a radius equal to the diameter of the shell, and the rear head is to be furnished with a man hole of the Hercules pattern approximately 10x16 inches in size. At the forward end of the drum is to be located a baffle plate extending towards the rear a distance of about 6 feet and located directly underneath the steam opening, so as to prevent any entrainment in the steam. A sufficient opening is to be left between the top edge

of the baffle plate and the top of the shell to give an area equal to at least one and one-half times the area of the steam opening. For details of steam basket, see paragraph attached to back of specification, reading Steam Basket.

This drum is to be furnished with a cast steel tee flange having an internal diameter of 5 inches, and riveted to the top of the shell, a distance of 24 inches between the center of the same and the front edge of the shell plate. This tee is to be furnished with a flanged connection at the top for the attachment of 3½-inch pop safety valve.

A 2-inch feed pipe connection is to enter the front head of this drum as near the bottom as possible, extending towards the rear, and arranged to discharge directly over the opening leading to the rear water leg. The feed pipe is to discharge into an oval mud drum described in the paragraph entitled Mud Drum and attached to the back of this specification.

The shell plate of this circulating drum is to be cut away at the points where it joins to the water legs; this opening to be reinforced by means of two plate steel throat stays made of ½-inch flange steel thoroughly riveted to the same.

All shell plates are to have a thickness of ¾ inch, and the heads a thickness of ½ inch.

The circumferential seams are to be furnished with single riveted lap joints, and the longitudinal seams with triple riveted lap joints. The details of these joints are given in the blue print hereto attached.

Buck Stays.—Six (6) buck stays are to be furnished with this boiler. These buck stays are to be of the channel pattern made in accordance with a detailed sketch to be furnished by thetie rods of

..... round iron, provided with all the necessary nuts and washers, and of sufficient length to extend entirely across the width of the setting, are to be furnished with the buck stays.

Trimnings.—This boiler is to be furnished with one $3\frac{1}{2}$ inch nickel seated pop safety valve set to blow at 110 pounds per square inch, one 2-inch feed valve, one 2-inch check valve, two $1\frac{1}{4}$ -inch asbestos-packed blow-off cocks, one water column fitted with $1\frac{1}{2}$ -inch pipe connections to boiler, three $\frac{3}{4}$ -inch Pittsburg gauge cocks, one $\frac{3}{4}$ -inch glass water gauge with brass valves and guard rods, and one 10-inch steam gauge with syphon. Gauge cocks to be fitted with chains and handles of sufficient length so they can be operated from floor.

Castings.—This boiler is to be furnished with one special type water tube boiler front, a sufficient number of cast iron grate bars for covering a width of $54\frac{1}{2}$ inches, and a length of 54 inches, one back grate bearing bar, two (2) soot doors and frames, one set of back wall supporting plates, and one set of saddles for locating underneath the rear water leg.

Boiler Support.—The front water leg is intended to be supported by means of cast iron columns located in the lower section of the boiler front, and the rear water leg by means of a low supporting wall.

Tube Tile.—A full set of fire clay tube tile is to be furnished for covering the top and the bottom rows of tubes.

Tile Bars.—Two tile bars made of $1\frac{1}{4}$ -inch square iron are to be furnished for this circulating drum. These bars are to be held in place by means of wrought iron hangers located at intervals of four feet, and securely

bolted to the shell; the purpose of the bars being to support the ends of the tiling, closing in around the drum.

Fire Tools.—This boiler is to be furnished with a set of fire tools, consisting of S-wrench, one $\frac{1}{2}$ -inch soot blower, furnished with about 10 feet of steam hose, connection for the soot blower is to be furnished at the front and back ends of the boiler, and one $3\frac{1}{2}$ -inch tube scraper, with handle.

Smoke Hood.—A smoke hood made of No. 8 gauge steel is to be furnished and located on top of the boiler. This is to be approximately 4 feet in height, and designed in accordance with detailed drawing to be furnished by The top is to be rounded and furnished with a band riveted a distance of about 4 inches below the top edge for supporting 32-inch diameter smoke stack. Hood to be reinforced by angle iron and small door to be located near bottom for cleaning. Put in damper No. 8 steel and furnish lever and chain so as to permit operation from floor.

Smoke Stack.—One smoke stack is to be furnished with this boiler having a diameter of 32 inches, and a height of 80 feet. This stack is to be fitted with a $3\frac{1}{8} \times 2\frac{1}{2}$ -inch band riveted around outside edge at top, and a $\frac{1}{2} \times 3\frac{1}{2}$ -inch band riveted around bottom edge on outside. Fit the top band with two paint rings made of $\frac{5}{8}$ -inch round iron, and about 5 inches in length for attachment of painters' rigging.

There are to be riveted to the inside of this stack at the proper locations, two bands, each made of No. 10 gauge steel, and having a width of 12 inches for reinforcing the stack at the points where the guy bolts are to enter. Two sets, each consisting of four eye bolts are to be fitted to the stack at the points where these bands are located, for the attachment of $\frac{3}{8}$ -inch galvanized

strand guys. The eye bolts are to be fitted with clevises so that the strand can be fastened thereto. Two coats of black asphaltum paint are to be applied to stack; one when same is in shop, and the other after erection. A casing made of No. 12 sheet steel and of sufficient diameter to leave a clear space of 12 inches all around the smoke stack is to be furnished. This to be of sufficient height to extend above the roof a distance of about 2 inches. A weather apron to be bolted around stack, having a width of about 18 inches.

Testing and Inspection.—A hydrostatic pressure of 165 pounds per square inch is to be applied to this boiler before it leaves our works, and a certificate of said test, together with a policy of insurance for \$500.00 for one year, issued by any reliable boiler insurance company, is to be furnished.

Steam Basket.—A perforated basket is to be furnished and located directly beneath the steam opening, as an additional precaution for obtaining dry steam. This is to be provided with a sufficient number of $\frac{1}{2}$ -inch diameter holes to give an area equal to at least twice that of the steam opening.

Mud Drum.—An oval mud drum measuring 10 feet in length, 14 inches in width, $8\frac{1}{2}$ inches in height, and made of five sections, each about 2 feet in length, is to be located near the bottom of the shell of the circulating drum. This is to be made of No. 12 steel, with the exception of the back head, which is to be made of $\frac{3}{16}$ -inch steel. The back head is to be fitted with a small hand hole provided with the necessary plate and arch. A $1\frac{1}{4}$ -inch blow-off pipe connection is also to be screwed in this back head as close to the bottom as possible and extending out through the head of the circulating drum.

An opening in the shell of the mud drum is to be located at the front end, measuring about 14 inches in width by 15 inches in length. The oval drum is to be suspended from the inside of the shell of the circulating drum by means of three straps, located at equal intervals along the length of the same.

Water Column.—The water column is to be connected to the bottom of the shell of the circulating drum at the front end, in accordance with a sketch to be furnished.

Down Draft Furnace.—One down draft smokeless furnace is to be attached to the boiler. This is to consist of a front and a rear manifold joined together by means of a single row of extra heavy tubes, each having an internal diameter of $2\frac{1}{2}$ inches, and a length as measured between the shells of the manifold of 4 feet. These tubes are to be spaced a distance of 5.45 inch center to center, thus making a total of ten tubes to form the grate. The front manifold is to be connected to the boiler by means of two vertical 4-inch pipes, one on each side of the furnace, and connecting to the bottom of the front water leg on the back side by means of special cast steel tees. The rear manifold is to be connected to the circulating drum of the boiler by means of a 4-inch pipe located on each side. This pipe is to be bent; the use of ells to form the bend not being permitted. A collar made of No. 10 gauge steel is to be furnished for the outside end of the rear manifold. This collar is to have a length of 9 inches, and no rivets are to be used in the same. The plates being merely rolled up to size and the edges butted.

The blow-off connections for both the front and the rear manifolds are to be $1\frac{1}{2}$ -inch diameter; we furnish the necessary nipples and valves, but we do not connect the same up with the blow-off tank.

FORM OF SPECIFICATIONS FOR A SAFETY WATER TUBE BOILER.

Number, Type and Size.—There shall be boiler.. of the horizontal inclined water tube type, rated at horse power, the term horse power being understood to mean 30 pounds of water evaporated per hour from feed-water having a temperature of 100 degrees Fahrenheit into steam at 70 pounds gauge pressure.

General Description.—The boiler in all its main parts to be composed of plate steel. It is to consist of two water legs of equal size, approximately rectangular in shape, joined together by means of a series of vertical and horizontal staggered rows of tubes, and overhead circulating steam and water drum.. The drum.. and tubes are to be made parallel to each other, and the water legs made perpendicular to both. When boiler is erected, same must incline towards the rear a distance of 1 inch per lineal foot.

Plates.—All plates used in the construction of boilers .. are to be of the best open hearth homogeneous flange steel, having a tensile strength of 60,000 pounds per square inch of section. These plates are to be plainly stamped with the name of the manufacturer, the tensile strength and the quality said stamps to be so located as to be easily visible after the boiler.. has been completed.

The thickness required for these plates are given under the various paragraphs relating to the specific parts of the boiler herein described.

Tubes.—..... boiler is to contain tubes, each having an outside diameter of $3\frac{1}{2}$ inches, and a length of feet. Each tube is to be of the best

lap-welded quality standard gauge in thickness, and made of The ends of all tubes are to be thoroughly expanded into the tube plates of the water legs.

The distance from center to center horizontally of the tubes is to be $7\frac{1}{4}$ inches, and the distance vertically is to be 5 inches, except that between the bottom row and the next row above, which is to be $8\frac{1}{2}$ inches, so as to permit the introduction of a course of tile on top of the lower row.

Water Legs.—..... boiler is to be furnished with two water legs, each consisting of a tube plate, and a hand hole plate joined together by means of a strap riveted around the outside. These plates are to be so arranged as to leave a clear space of 10 inches between them on the inside.

The hand hole plate of each water leg is to be furnished with a series of oval hand holes, each measuring $3\frac{5}{8}$ inches by $4\frac{3}{4}$ inches in size, and furnished with a heavy cast iron cover plate, one four-prong arch, one bolt and a lead gasket. A hand hole is located directly in front of each end of each tube so as to permit easy access for cleaning.

The water leg plates are to be thoroughly stay-bolted together by means of hollow stays, each having a minimum outside diameter of 1 9-16 inches, spaced a distance of $7\frac{1}{4}$ inches center to center horizontally, 5 inches center to center vertically.

Castings.—..... boiler is to be furnished with one standard type water tube boiler front, a sufficient number of cast iron grate bars for covering a width of inches, and a length of inches, one back grate bearing bar, two (2) soot doors and frames, one set of

back wall supporting plates, and one set of saddles for locating underneath the rear water leg.

Boiler Supports.—The front water leg is intended to be supported by means of cast iron columns located in the lower section of the boiler front, and the rear water leg by means of a low supporting wall.

Tube Tile.—A full set of special fire clay tube tile is to be furnished for covering the top and the bottom rows of tubes.

Tile Bars.—Two tile bars made of $1\frac{1}{4}$ -inch square iron are to be furnished for circulating drum. These bars are to be held in place by means of wrought iron hangers located at intervals of four feet, and securely bolted to the shell; the purpose of the bars being to support the ends of the tiling, closing in around the drum.

..... drum is to be furnished with a flange having an internal diameter of inches, and riveted to the top of the shell, a distance of inches between the center of the same and the front edge of the shell plate.

A inch feed pipe connection is to enter the front head of drum as near the bottom as possible, extending towards the rear, and arranged to discharge directly over the leading to the rear water leg.

All seams around the perimeters of the water legs are to be furnished with single riveted lap joints with rivets spaced a distance of 2 inches center to center, and having a diameter, after being driven, of $13/16$ inch. At the throats, where the legs are attached to the circulating drums, double riveted lap joints are used.

Circulating Drum.—..... boiler to be furnished with drum.. for permitting the circulation of

the water from the front water leg to the rear water leg, and also affording a steam space in the upper half. drum is to have an internal diameter of inches, and a length of shell of feet inches. The heads of drum.. are to be dished to a radius equal to the diameter of the shell, and the rear head is to be furnished with a man hole of the Hercules pattern approximately 10x16 inches in size. At the forward end of drum is to be located a baffle plate extending towards the rear a distance of about 6 feet and located directly underneath the steam opening, so as to prevent any entrainment in the steam. A sufficient opening is to be left between the top edge of the baffle plate and the top of the shell to give an area equal to at least one and one-half times the area of the steam opening.

Trimnings.— boiler is to be furnished with inch pop safety valve set to blow at pounds per square inch, one feed valve, one check valve, 1¼-inch asbestos-packed blow-off cocks, one water column fitted with 1½-inch pipe connections to boiler, three ¾-inch gauge cocks, one ¾-inch glass water gauge with brass valves and guard rods, and one steam gauge with syphon.

The shell plate of circulating drum is to be cut away at the points where it joins to the water legs; this opening to be reinforced by means of plate steel throat stays made of ½-inch flange steel thoroughly riveted to the same.

All shell plates are to have a thickness of inch, and the heads a thickness of inch.

The circumferential seams are to be furnished with single riveted lap joints, and the longitudinal seams with riveted joints.

Buck Stays.—..... () buck stays are to be furnished with boiler.. Each buck stay is to consist of two rolled steel angles, $3\frac{1}{2}$ inches by $3\frac{1}{2}$ inches by $\frac{3}{8}$ inch in size, bolted together back to back at intervals of about three feet and separated by means of thimbles placed on the outside of the bolts, a distance of $1\frac{1}{4}$ inches throughout the entire length. tie rods made of round iron, provided with all the necessary nuts and washers, and of sufficient length to extend entirely across the width of the setting, are to be furnished with the buck stays.

Fire Tools.—..... boiler.. to be furnished with a set of fire tools, consisting of a scoop, hoe, rake and slice bar. There is also to be furnished one $3\frac{1}{2}$ -inch tube scraper with handle.

Smoke Stack.—..... smoke stack is to be furnished with boiler.. having a diameter of inches, and a height of feet

Testing and Inspection.—A hydrostatic pressure of pounds per square inch is to be applied to boiler before it leaves the works, and a certificate of said test, together with a policy of insurance for \$. for one year, issued by any reliable boiler insurance company, is to be furnished.

FORM OF SPECIFICATIONS FOR A HORIZONTAL TUBULAR BOILER.

Number, Type and Size.—There shall be boiler of the Horizontal Tubular Type, each having a diameter of inches and a length, as measured from out to out of heads, of feet inches.

Tubes, Arrangements, Etc.—..... boiler is to contain tubes, each having an outside

diameter of inches and a length of feet. Each tube is to be of the best lap-welded quality, standard gauge in thickness and made of All tubes are to be thoroughly expanded into the tube holes of the heads, and after this is done the ends are to be neatly beaded over by means of round-nosed tools, driven by pneumatic pressure. The tubes are to be arranged in vertical and horizontal rows, with a clear space of one inch between them, vertically and horizontally, except the central vertical space, where a distance of two inches shall be allowed.

Plates, Quality, Thickness, Etc.—All plates used in the shell of boiler.. are to be made of the beststeel, having a tensile strength of not less than 60,000 pounds per square inch, and a thickness of The heads are to be made of the best open hearth homogeneous flange steel, of the same tensile strength as that mentioned for the shell plates and having a thickness of

All plates are to be plainly stamped with the name of the manufacturer, the tensile strength and the quality, said stamps to be so located as to be easily visible after the boiler been completed.

Riveting.—The longitudinal seams are to be furnished with riveted joints, with all rivets so arranged as to come well above the fire line.

Bracing.—The boiler heads are to be braced by means of weldless steel crow-foot braces, having a diameter of inches, so as to be of equal strength as the boiler shell.

Dry Pipe.—A dry pipe is to be located on the inside of boiler shell and is to be connected to the steam opening by means of a special tee, located in the center. This dry pipe is to be closed at both ends

and is to be furnished with a sufficient number of $\frac{1}{2}$ -inch diameter holes located on the upper side to give an area equal to twice that of the steam opening. Both ends are to be closed and a $\frac{1}{4}$ -inch diameter drip hole is to be located on the bottom of the dry pipe near each end.

Man Holes.—A man hole of the Hercules pattern is to be located in the front head beneath the tubes, and another

Castings.—..... boiler.. to be furnished with a fire front of the pattern. boiler is to be furnished with a sufficient number of standard cast iron grate bars to cover a width of inches and a length of inches; one back grate bearing bar; one soot door and frame; skeleton arch plates. boiler.. to be furnished with buck stays, provided with tie rods, nuts and washers.

Trimings.—..... boiler is to be furnished with one safety valve; one blow-off valve; one feed valve; one check valve; one combination steam and water column, with pipe connections to boiler; three gauge cocks; one glass water gauge, with brass valves and guard rods; and one steam gauge; with syphon.

Breeching.—.....

Smoke Stack.—One smoke stack is to be furnished for boiler.. having a diameter of inches and a height of feet, made of sheet steel, and furnished with feet of galvanized strand for guys.

Boiler Supports.—.....

Testing and Inspection.—A hydrostatic pressure of pounds per square inch is to be applied to boiler before it leaves our works, and a certificate of

said test, together with a policy of insurance for for one year, issued by any reliable boiler insurance company, is to be furnished.

FORM OF SPECIFICATION FOR INTERNAL FURNACE BOILER OF ... HORSE POWER.

Generally.—The boiler is to be of ... horse power (one horse power to mean $34\frac{1}{2}$ pounds of water evaporated per hour from a feed water temperature of 212 degrees Fahrenheit into steam at atmospheric pressure), and in all respects properly proportioned for a steam pressure of ... pounds per square inch.

Material.—The material from which the boiler is to be constructed shall be of open hearth flange steel, 60,000 pounds tensile strength. In a parallel test piece, 8 inches long, when tested to destruction, the elongation shall not be less than 25 per cent, and the elastic limit shall not be less than one-half the ultimate tensile strength. A similar test piece, shall permit of its ends being bent cold in a parallel direction, about a curve, whose inner radius shall not be more than the thickness of the test piece. This test to be made without fracture at any point.

The shell of the boiler to be inches, inside diameter, and inches, in thickness. The distribution of the plates, and also of the rivets, of the various joints to be, as shown by the drawing.

The front and rear heads are to be inches thick, and to have their circumferential flanges of such diameter, as to properly fit the shell. These flanges to be turned to an internal radius of not less than one inch. The flanges of the furnace openings, in both the front and rear head, to be turned inward (in respect to

the boiler) and to be of sufficient lengths for single rows of rivets. The furnace opening of the front head, should be $\frac{1}{4}$ of an inch greater in diameter, than the furnace opening of the rear heads, to permit of the easy insertion of the furnace into position.

Furnace.—The furnace to be of the Morrison suspension type, inches, inside diameter, by feet, and inches long, and inches thick, having plain parts, at the front and rear ends, of sufficient length to be single riveted to the furnace opening flanges of the boiler heads.

Tubes.—The boiler will contain tubes, inches outside diameter, spaced inches centers, and located as shown on the drawing.

Back Connection.—The rear course of the boiler shell, is to extend about $2\frac{1}{2}$ inches, beyond the flange of the rear head, and to it, is to be bolted an extension forming a back connection. This extension may be of ordinary "tank steel" of sufficient width to provide for a combustion chamber, having a clear depth of 30 inches. Riveted to the inside of this extension, at its outer end, is to be a ring of $2\frac{1}{2} \times 2\frac{1}{2} \times 5/16$ -inch angle, to which will be bolted a head of ordinary "tank steel," made in two pieces, joined together by bolts, as shown on the drawing. In the lower portion of this head, there is to be an opening surrounded by an angle iron ring, forming a door frame, 18 inches wide, by 15 inches high, to which will be fitted a suitable door, provided with latch, hinges and baffle plate. Across the head, there should be a stiffening angle bar.

The inside circumference of the combustion chamber, is to be lined with fire brick, placed on edge, forming a lining $4\frac{1}{2}$ inches thick. This lining should extend circumferentially upward, to a point one inch above the

top of the upper row of tubes. The back of the combustion chamber should be lined with fire brick, 9 inches thick. This lining of the rear head, or back end, should be carried to the same height as the circumferential lining, and the opening at the top bridged over by fire brick tiles, about 5 inches thick. One end of the tiles to rest upon an angle bar, riveted to the back head of the boiler, the other end upon the rear lining of the chamber.

Rivets.—The rivet holes are to be either drilled, or punched $1/16$ of an inch small, then reamed to requisite size. No drifting of unfair holes will be permitted. The rivet holes, at the furnace ends, are to be countersunk on the inside, and the rivets driven upon the inside of the furnace, leaving slightly spherical rivet heads.

The boiler heads are to be braced with through bolts, inches diameter, upset at each end to inches diameter, and threaded. They are to be secured to the heads, with outside hexagonal nuts, provided with washers 8 inches in diameter, and of $6/10$ the thickness of the boiler heads. Upon the inside, there are to be suitable washers and nuts (of half thickness) screwed up tight against the head. If preferred, the flat surfaces of the heads may be braced by means of the McGregor Solid Steel Braces, instead of the through bolts, as above described, in which case the braces are to be of sufficient number, and so located, as to thoroughly stay the heads.

Man and Hand Hole Openings.—Upon the top of the shell, there is to be located an Eclipse Man Hole and cover, 10x16-inch opening, provided with the usual clamps and bolt. In the front head, below the tubes, there are to be located hand hole and man hole openings, as shown, fitted with suitable covers and guards. The

openings in the shell and heads are to be reinforced by strengthening pieces, of unequal section to the plate, in which the holes are cut, and securely riveted on the inside of the boiler.

Front Connection.—The front connection, to be of the general design shown by the drawing, and to be made of sheet metal $\frac{3}{16}$ of an inch thick, secured to the front head of the boiler, by $2\frac{1}{4} \times 2\frac{3}{4}$ angles and stud bolts, to have an interior lining of metal, $\frac{1}{8}$ of an inch thick, spaced 1 inch asunder, by means of thimbles. At its upper portion, it will be drawn to a suitable shape, and surrounded by a ring $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ angle, to provide for the reception of a smoke stack, inches in diameter. The front of the connection is to be provided with a door, fitted with forged hinges and latches, for securing it in place. The door to be provided with a lining, affording a 1-inch air space.

Furnace Doors, Etc.—The front of the furnace, is to be closed by a Morrison Protector Furnace Front and Door, and below it, is to be fitted a sheet iron ash pit door, provided with two forged handles and proper means for holding it in position.

Grate and Bridge Wall.—There is to be a cast iron bridge wall, topped with fire brick, placed in the furnace, in a suitable position to provide for a grate area of square feet. Midway between it and the dead plate, of the furnace front, is to be located, a double bearer bar, the ends of which are to rest upon suitable supports. The grate bars to be of cast iron, provided with openings to suit the character of fuel to be used. Beneath the grate is to be an ash pan, formed of $\frac{1}{8}$ -inch ordinary "tank steel," bent to shape, and extending from the bridge wall to front of furnace.

into the head. Where the boiler is to be set with $\frac{3}{4}$ arch fire front, these connections are made in the shell near the front end. The rear connections are made by running 5-inch extra heavy pipe from the rear manifold and connecting into the back head of the boiler in same manner as the front connections when set with full flush or $\frac{3}{4}$ arch front, except where space in rear of boiler will not permit, in which case the connections are made in the upper quarter of the boiler directly above the rear manifold.

Fire Fronts.—Each furnace is supplied with a fire front, either of the full flush or three quarter arch pattern as may be desired. These fronts are supplied with fire liners, front bearing bars, Pickle patent fire doors, also ordinary lower doors and ash pit doors.

These furnaces can be attached to boilers already in position, as well as to new boilers, by making the necessary change in fire fronts and removing and replacing brick work, and also providing for the necessary support of the front end of the boiler, except where same is already supported independent of the fire front.

Dimensions of Water Tube Boilers.—In Table No. 16 is given the average dimensions of water tube boilers.

SPECIFICATIONS FOR LATEST IMPROVED DOWN DRAFT SMOKELESS FURNACES.

Manifolds.—The front and rear manifolds of these furnaces are made of special lap-welded steel tubing 8 inches in diameter, of the highest quality, made especially for the purpose. Thickness of metal in these manifolds $\frac{3}{8}$ of an inch. Heads flanged and riveted in, hand plate in one end, thickness of heads $\frac{3}{8}$ -inch of open hearth flange steel. The rear drums have two special forged steel flanges riveted on for 5-inch pipe and the front drums have flanges for 4-inch pipe.

Connecting Tubes.—The grate tubes connecting the two manifolds are 2 inches in diameter and $2\frac{3}{8}$ inches outside diameter, a double staggered row properly spaced. They are made of special cold drawn seamless steel tubing. The tubes are screwed into the rear manifold and expanded into the front manifolds. The length of the tubes are from 4 feet to $5\frac{1}{2}$ feet according to the length of the boiler.

Brass Plugs.—In the front manifolds there are $2\frac{1}{4}$ -inch brass plugs screwed in, one opposite each grate tube for inspection and washing, a panel being placed in the fire front fastened on with small lugs and screw bolts giving free access to these brass plugs. By loosening up the cap screws slightly the lug can be turned so that the panel can be readily removed and replaced.

Connections.—The connections between the furnace and boiler are made of extra heavy pipes with steel or semi-steel fittings, the front connections being 4 inches in diameter and the rear connections 5 inches in diameter. Where boiler is set with full flush fire front the front connections are made through the head of the boiler by means of 4-inch boiler tube being expanded

into the head. Where the boiler is to be set with $\frac{3}{4}$ arch fire front, these connections are made in the shell near the front end. The rear connections are made by running 5-inch extra heavy pipe from the rear manifold and connecting into the back head of the boiler in same manner as the front connections when set with full flush or $\frac{3}{4}$ arch front, except where space in rear of boiler will not permit, in which case the connections are made in the upper quarter of the boiler directly above the rear manifold.

Fire Fronts.—Each furnace is supplied with a fire front, either of the full flush or three quarter arch pattern as may be desired. These fronts are supplied with fire liners, front bearing bars, Pickle patent fire doors, also ordinary lower doors and ash pit doors.

These furnaces can be attached to boilers already in position, as well as to new boilers, by making the necessary change in fire fronts and removing and replacing brick work, and also providing for the necessary support of the front end of the boiler, except where same is already supported independent of the fire front.

Dimensions of Water Tube Boilers.—In Table No. 16 is given the average dimensions of water tube boilers.

CHAPTER IX.

QUESTIONS AND ANSWERS ON PRECEDING CHAPTERS.

Q. What is the difference between a plain tube and a submerged tube vertical boiler?

A. In a plain tube, or dry top boiler as it is sometimes called, the **ends** of the tubes are not covered with water, while in the submerged tube boiler the **ends** of the tubes are submerged or kept covered with water at all times.

Q. Which type of these boilers is preferable?

A. The submerged tube type, as the tubes and tube sheet are less likely to be **burned**.

Q. How are vertical boilers usually set?

A. The smaller types are self contained, while the larger boilers rest on a foundation built in the ground.

Q. Are the Cornish and Lancashire boilers externally or internally fired?

A. They are **internally** fired.

Q. How are vertical boilers fired?

A. They are **generally internally** fired.

Q. How are return tubular boilers fired??

A. They are **externally** fired.

Q. What are the advantages claimed for internally fired boilers?

A. That they are more **economical** in the use of fuels, and also are **self contained**.

Q. What is the chief objection to internally fired boilers of the Cornish and Lancashire types?

A. The liability of the flues to **collapse**, owing to the steam pressure being on the outside of them.

Q. Why are the tubes in a water tube boiler set at an angle, or inclination?

A. To facilitate the circulation.

Q. How much is this inclination?

A. Usually one inch to twelve feet of tube.

Q. Why are water tube boilers claimed to be safer than fire tube boilers?

A. On account of the small amount of water contained in the tubes of same, and also owing to the small diameter of the tubes.

Q. Name some of the advantages of water tube boilers?

A. They are, (1) safety from explosion; (2) tubes less likely to rupture; and (3) their quick steaming qualities.

Q. Name some of the advantages of the internal furnace boiler?

A. The chief advantage of this type of boiler is the economy of first cost, they being "self contained," therefore the expense of setting is saved.

Q. What is meant by a "self contained" boiler?

A. A boiler that is independent of any masonry setting, cast iron fronts, buck stays, tie rods, and etc., thus permitting them to be easily removed from one locality to another.

Q. What other advantages do they possess?

A. They are capable of carrying an extremely high steam pressure, and are at the same time steady steamers. They are extremely economical in the consumption of fuel owing to the absence of all brick settings, which settings usually crack and allow the heat to escape.

Q. What is the principal advantage of the multi-tubular boiler?

A. Its cheapness.

Q. What stationary boiler is most generally used in this country?

A. The multitubular boiler.

Q. How is **boiler steel** usually made?

A. It is made by the **open hearth** process.

Q. What is the chief ingredient of all commercial iron and steel?

A. Pure iron, of which they contain from 93 per cent to 99 per cent.

Q. What is the principal difference between wrought iron and steel?

A. The amount of **carbon** contained in them. To make steel from pig iron it is necessary to burn the carbon out of the iron, and to make it from wrought iron it is necessary to add carbon to it.

Q. What is meant by the open hearth process?

A. In this process the gas and air needed for combustion are heated to over 1,000 degrees Fahrenheit before entering the combustion chamber. To the molten metal certain chemicals are then added to keep it in a state of agitation, which takes the place of puddling or stirring it.

Q. What is the Bessemer process?

A. In this process the molten pig iron is put into a large pear-shaped vessel called the "Converter," and air is forced through it under pressure. The air passing through the molten metal burns out the carbon, silicon, etc.

CHAPTER X.

LEADING TYPES OF BOILER AND FURNACE ATTACHMENTS.

Pressure Gauges.—In Fig. 69 is shown a sectional view of the Bourdon Steam Gauge, which is the standard pressure gauge now in use. The principle upon which this gauge is constructed has heretofore been explained.

Pressure Recorder.—In Fig. 93 is shown a pressure recorder. This device, or recorder, can be used on steam, gas, water and all forms of pressure, to correctly record the fluctuations and pressure for a given time. With these instruments, is usually furnished an ample supply of charts, ink, etc., also printed instructions.

By using such pressure recorders, the fluctuations in the steam are correctly recorded in ink upon a chart, which permits the operation of the boiler to be inspected daily. Such recorders are therefore a great assistance to the chief engineer in keeping a careful oversight over the firing of the boilers, and the labor of attendants.

Gauge Frame.—In Fig. 94 is shown a gauge frame for the engine room, which permits the engineer to know at all times exactly what is being done in his plant.

THE LUNKENHEIMER POP SAFETY VALVE.

Construction.—In Fig. 95 is shown a well known type of a Pop or Spring Safety Valve. These valves consist of the iron body A into which is firmly screwed the bronze seat ring E, having a bevel seat at an angle of 45 degrees. The seat ring is provided with the regulating ring F, which can be screwed up or down to regulate the pop and is held in any desired position by means of the regulating ring screw H. The disc D is well



A Pressure Recorder.

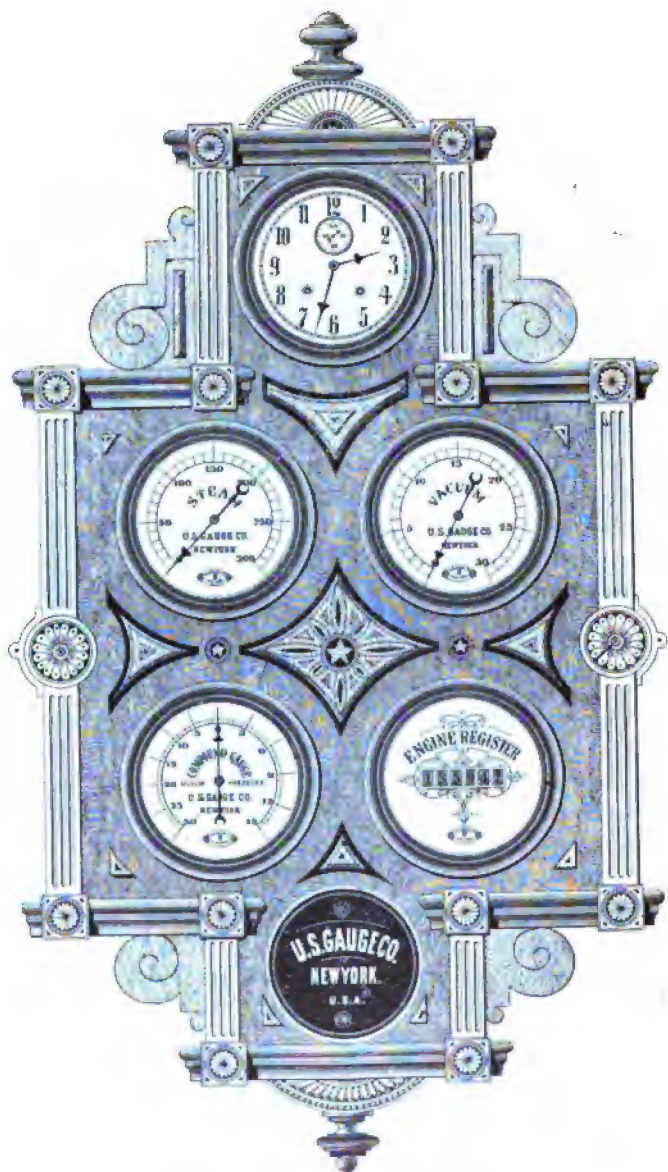
Fig. 93

guided by means of the wings on the bottom thereof operating inside the seat ring E. The disc lock-nut G permits of the disc being raised from its seat by means of the easily operated compound lever K, as the spring holder R, which is rigidly secured to the stem X, has projecting wings on same which engage the under part of said lock-nut. By turning the stem X the disc D can readily be reground, as the wings on the spring holder R engage correspondingly shaped recesses in the disc. The large steel spring J is firmly held in place by the top and bottom plates Q and P, and it will be observed that these plates have ball shaped bearings at both top and bottom, which at all times insure perfect alignment of the spring. The casing forming part of the top B thoroughly encases the spring J, and the action of the disc can not be affected by back pressure should the discharge pipe be cramped or muffled, as the top of same operates within a bronze spring casing ring.

The top B is securely held to the body by large steel studs, while the bonnet C is in turn held to the top by large bronze cap screws. The tension of the spring J is regulated by means of the regulating screw M which operates in the bronze bushing O. The lock-nut N holds the regulating screw in any desired position.

It is not necessary to change the pressure adjustment when testing the boiler, as the screw S can be removed, and a long set screw of the same diameter inserted and screwed down upon the valve stem, holding the disc to its seat while the pressure is being applied to the boiler. As soon as the test is over the set screw can be removed and the valve will again be as efficient as ever.

To take the valve apart, remove the lever K and fork L, take off the bonnet C and relieve the load on the spring by unscrewing the set screw M, after which the



A Gauge Frame for Engine Room.
Fig. 94.

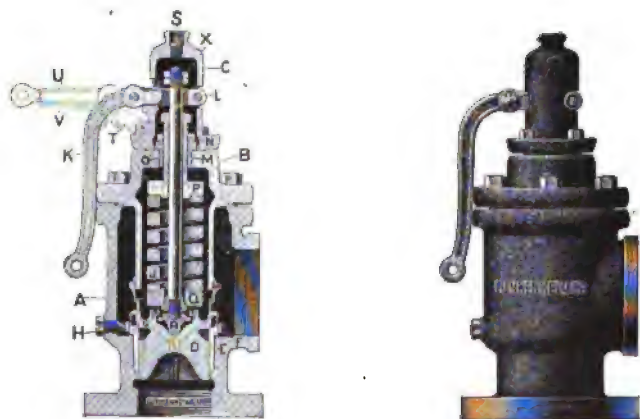
top B can be removed, when access to the interior can readily be had.

To set the valve at a higher pressure, turn the regulating screw M down, and for a lower pressure, turn regulating screw up. The pop or action of the escaping steam is regulated by the ring F, which is easily accessible without taking the valve apart by removing the screw H and inserting a rod to engage the notches around the regulating ring F. If the valve pops suddenly, and does not reduce the pressure enough, turn ring F up, which covers the holes in the seat ring and causes the disc to remain longer off its seat. If the valve pops too much, opening and closing only gradually, turn the ring F down. When the desired adjustment is obtained, secure the ring F by means of the screw H.

Quick Closing Water Gauge.—In Fig. 96 is shown the Huyette Quick Closing Water Gauge. It is impossible to prevent the breaking of water glasses, owing to their sudden expansion when steam is raised in the boiler, and the sudden release of the steam upon their breaking is a source of constant danger to the engineer, and of scalds or burns when trying to shut off the gauge when the glass breaks.

With a quick closing device all that is necessary is to pull the chain which is sufficiently long to always be in easy reach of the attendant, and which closes the gauge valve both at the top and bottom, as seen from the cut, thus preventing further escape of the steam.

Safety Water Column.—In Fig. 97 is shown the Wright Safety Water Column. The chamber shown at the bottom, is for the collection of sediment. The whistle is shown on top of the column. When the water varies above or below the proper level, the whistle sounds an



The Lunkenheimer Pop Safety Valve.

Fig. 95.

alarm, and continues to blow until the feed water supply has been regulated.

THE COCHRANE FEED WATER HEATER AND PURIFIER.

Fig. 98.

Construction.—Each side of this heater is formed of one or more strongly ribbed cast iron plates, bolted together at the flanges and made steam and water tight with rust joints calked from the inside; suitable stay tubes and bolts are used in the larger sizes, so that the shells, being strong and rigid, will not be affected by the pulsations of the exhaust steam. The top and bottom plates are also of cast iron, the latter being either dished or set at a slight angle to permit of complete drainage through the blow-off pipe.

The Oil Separator.—The Cochrane Oil Separator, through which the exhaust steam enters the heater, is bolted on the outside of the shell. The separator is self-cleaning, and is drained through a drip pipe connected to the water seal on the waste pipe.

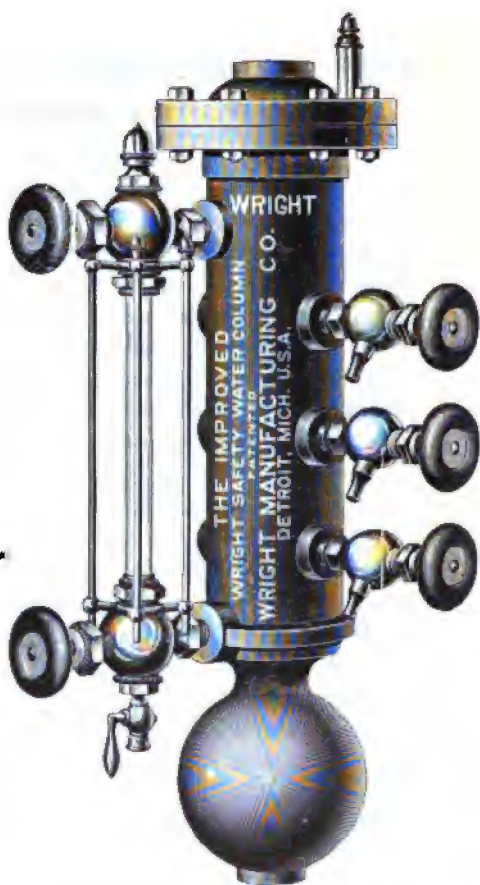
The Trays.—The upper portion of the heater contains the trays, which are interchangeable and removable, and which vary in number and arrangement according to the size of the heater; each is inclined, and the edge over which the water flows is serrated, or saw-toothed, for breaking up the water.

The trays are held in place by cast iron guides, securely bolted to the shell of the heater in such a manner that they cannot be dislodged by the pulsations of the exhaust, though they can be readily removed through the cleaning door openings.

Each set of trays is suspended in the steam space,



The Huyette
Quick Closing Water Glass.
Fig. 96.



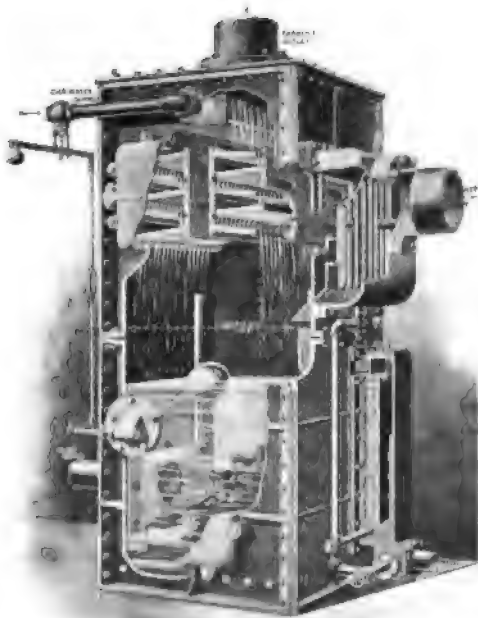
The Wright Safety Water Column.
Fig. 97.

with passages between the tray supports and the sides of heater, (and between the sets of trays in heaters having two or more sets), giving greater area for the passage of any surplus exhaust through the heater than the area of the exhaust inlet opening. This arrangement provides for delivering steam, by induction, through the opening in the tray guides to the water as it flows from tray to tray.

Introduction of the Water.—From the cold water opening in the heater the cold water is conducted to an open distributing box, or trough, extending across and above the trays. Over the serrated sides of the distributing box the water flows to the upper trays.

Controlling the Water Supply.—Outside of the heater, on the inlet pipe, is placed a balanced valve for regulating the cold water supply, which valve is controlled by a ventilated copper float carried in the heater. Any change in the level of the water raises or lowers this float, opening or closing, by crank and lever connections the regulating valve, thus keeping supplied the demands that are being made upon the heater for hot water, and preventing any waste of water through the overflow. The ventilation of the float is accomplished by using a hollow brass stem connected to a hollow axis, the end of which projects without the heater. A suitable brass stuffing box prevents leakage, the lower portion of the stem of the float being submerged, so that any water that may accumulate in the float from sweating through the copper, or from leakage, will show on the outside of the heater, within plain view of the engineer.

Skimmer, Overflow and Water Seal.—Just above the working level of the water, and extending the width of the heater, is placed a skimmer for taking off impurities that rise to the surface. Back of this skimmer is a



The Cochrane Feed-Water Heater and Purifier.
Fig. 98.

trough or overflow which is drained through an opening in the side of heater into the water seal or trap, which seal, while of ample size and perfectly open, carries a sufficient head of water to withstand a pressure of about one-half pound to the square inch.

Plates for Carrying Filter Bed.—To provide for carrying additional depositing surface in the form of a filter bed, this heater is furnished with perforated cast iron plates or shelving, on which the material used is placed, thereby insuring the passage of all the water through the filtering bed, and providing an easy course to the pump supply via the hood. These plates form a false bottom, being set at least four inches above the bottom of the heater.

Protection to Pump Supply Pipe.—Covering the outlet to the pump, and extending down to the coke shelving, is a hood, open at its under edge for the passage of water, and vented by a pipe at the top to prevent possible air-logging and consequent interference with the flow to the pump. This pipe also prevents the syphoning of water from the heater, thus maintaining a seal for keeping the floating impurities from the pump supply pipe.

Every provision is made for examining and cleaning all parts of the heater without disturbing any pipe connection, the openings being of large size and conveniently located.

THE WEBSTER FEED-WATER HEATER AND PURIFIER.

Fig. 99.

Construction.—The Webster "Star-Vacuum" Feed-Water Heater, Purifier, Filter and Receiver, consists of



The Webster Exhaust Steam Feed Water Heater and Purifier.
Fig. 99.

a cast iron receptacle in which cold water and exhaust steam are brought into direct contact.

The illustration shows clearly the construction and operation of a very well known style, built for boiler capacities of from 500 to 5,000 horse power. It is of the standard Webster type—an exhaust steam feed-water heater, in combination with a filter and precipitating chamber.

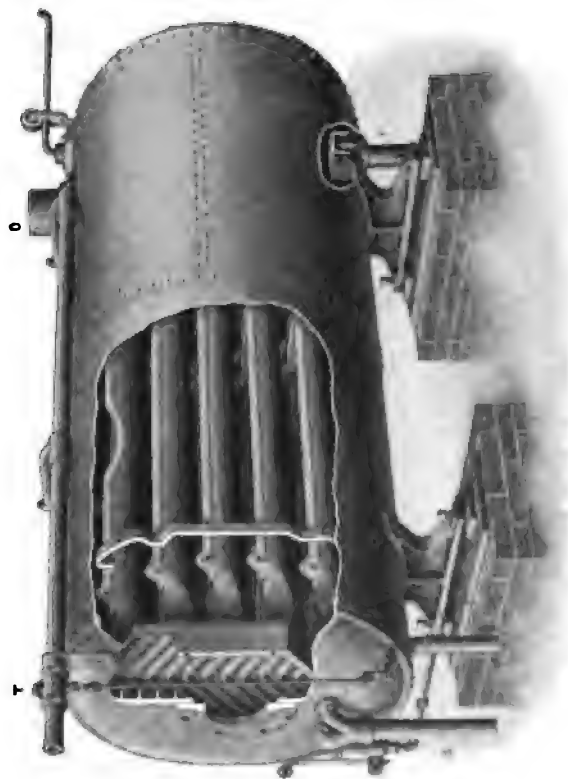
The heater is further provided with a Webster Oil Separator, which is made a part of the heater construction, which effectually and completely removes the oil present in the exhaust steam before it enters the heater; also with automatically regulated water supply and overflow; quick-opening drain valve or blow-off; sealed outlet for the heated and purified water fed to the boiler feed-pumps; charging and cleaning doors for the filter; removable tray doors; combination vent and inlet air valve; gauge glass, and other fixtures.

The materials used in its construction are cast iron for the shell, and copper and brass for the valves and fixtures; each of which resist the destructive action of impure waters. The large heating chamber—upper section of the heater—is provided with perforated copper trays for the distribution of water as hereinafter explained. The entire valve gear, automatically controlling the water supply and overflow, is of brass.

THE HOPPE'S EXHAUST STEAM FEED-WATER HEATER.

Fig. 100.

Description.—The shell is of steel plate, and heads are of cast iron, the front one being removable for taking out the pans for inspection or cleaning.



The Hoppe's Exhaust Steam Feed Water Heater.

Fig. 100.

The exhaust steam enters at the back end, and after passing through the large oil eliminator, the purified steam enters the heater proper, from which it escapes through the pipe O at front end.

The water, on entering the heater at T, is fed into the top pan and, overflowing the edges, follows the **underside** of the pan to near center, when it drops into the next pan below. It flows over each successive pan in the same manner until it reaches the chamber at the bottom, from which it passes to the pump through pipe P.

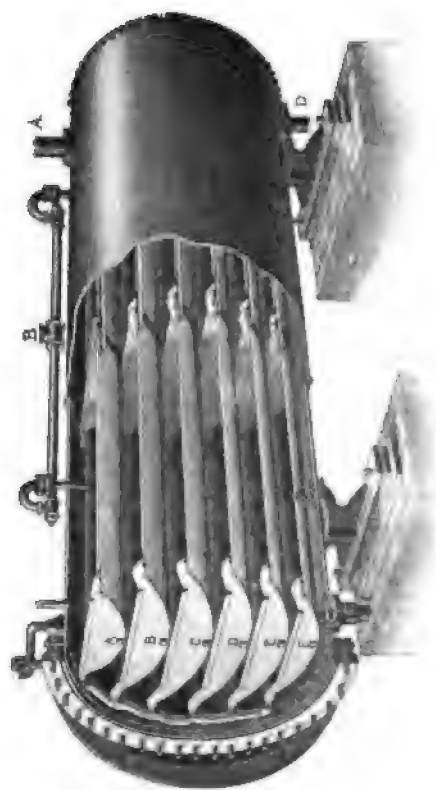
While the heater is in operation the water flowing along the **underside of the pans comes in direct contact with the exhaust steam** passing through the heater, and in this manner the water is heated without the heat having to pass through the pans or lime already formed thereon.

The **inside** of the pans afford settling chambers for the mud and solids in suspension, while the lime and other solids in solution form on the **underside of the pans**. The water is thus not only heated to the highest degree obtainable by exhaust steam, but all of the solids that are separated at that temperature are caught and retained in the heater.

Setting and Connection.—The heater should be set in a position that will bring the bottom of same **at least two feet above the suction-valves of the pump**. After the heater is placed on foundation it should be **leveled both ways** by the set-screws at corners, a spirit-level being placed on the leveling bar on top of heater.

The exhaust inlet should be connected at back end, and the outlet at the top. Connect the suction at P. B is blow-off or drain.

The water column may be placed on either side,



The Hoppe's Live Steam Purifier.
Fig. 101.

holes being provided in each side of heater for top connection, one of which is plugged. The overflow and oil-drip on small heaters are connected with a Y, and this should be connected to sewer. Where the heater is used in a heating system, a trap should be used in this pipe.

In attaching the float and valve, first secure the valve T in place, with arrow on side of valve pointing towards the heater.

Remove the head, take out the pans, and get inside of heater, and put the float in position by running the brass stem through the stuffing-box from the inside, replace the small iron lever on the outside end, drive in the pin, and connect the lever with the valve-stem by rod, as shown in cut.

The length of the rod can be adjusted to give any desired height of water in the heater. Carry the water just high enough not to run out of the overflow. A stop-valve should be placed on the feed-pipe to shut off the water, as the regulating valve is intended for regulation only.

THE HOPPE'S LIVE STEAM PURIFIER.

Fig. 101.

Construction.—The purifier consists of a round shell of best flange steel, having a solid, pressed flange steel head riveted in the back end, and a solid pressed flange steel head bolted to a heavy ring to the front end by studs and nuts. Within the shell are a number of trough-shaped pans or trays, placed one above another, and supported on steel angle-ways fixed longitudinally by means of brackets to the sides of the shell. These pans are formed from thin sheet steel, the heads or end

pieces being malleable iron, whereby a very light, strong and durable construction is obtained and a degree of elasticity or resilience secured to the pans, which permits the lime or other incrustations being easily removed. The ends of the pans are higher than the sides, and have projections at each extremity to rest on the ways on which the pans are adapted to slide.

The ways on which the top pans slide are curved downward opposite the feed inlets, to permit the heads of the pans to pass under the ends of the feed pipes.

The sectional cut illustrates a purifier with two tiers of pans and six pans in each tier, and the arrangements for dividing and distributing the feed-water in the top pan of each tier.

The purifier is connected to the boiler by a large steam pipe A and the exit or gravity pipe D. A blow-off pipe is also connected to the purifier at C.

The feed pipe from the pump or boiler feeder is attached at B.

A water column and gauge is also connected, as shown in the exterior view of purifier, and while in operation this gauge should never show more than half full of water.

In packing the head, round asbestos packing is placed in a groove turned in the ring, and is held in place by the head. This makes a most effectual and lasting joint, and dispenses with the use of large gaskets.

Setting and Connecting Purifier.—The purifier should set above the boilers, or in a position that will bring the bottom of shell two feet or more above the water-level of the boilers. After it is in position, the purifier should be leveled both ways by means of the set-screws at each corner. The main steam pipe A should be connected to an independent steam header,

unless the main steam pipe is large enough to supply the steam required for all branches leading from same without a reduction of pressure. B is the feed pipe from pump to purifier, and should have a check valve in it. D is the gravity pipe, through which the purified water flows to the boilers. This pipe should always be the full size of the flange, and branches to each boiler should not be less than 2 inches, with swing check valves. This pipe should be carried straight down below water-level of the boilers, and **all branches should be taken off below water line.** Where it is not possible to carry the pipe straight down from the purifier, 45 degree fittings should be used where bends are necessary above the water inlet. When horizontal runs are unavoidable above water line a good fall must be given. E is the direct feed to boilers, and extra precaution should be taken to have a tight valve in this pipe. We recommend two valves with a pet-cock between, as shown opposite. F is the steam connection from purifier to pump, which should be kept open when the purifier is in operation, and connection G closed. This is necessary in order that the air and non-condensable gases liberated from the water should be removed from the purifier. Should a steam pump not be used, this connection should be attached to some other steam-using device.

Shell.—The heater shell is rectangular in form. It is made up of sectional plates of close-grained cast iron, bolted and caulked by our patented ventilated rust-joint, as shown in illustration, which effectively prevents the rust-mixture from reaching the bolts.

The heater is easily cleaned, as the interior is accessible without disturbing any of the pipe connections. The large hinged doors may be opened, and the trays withdrawn. The lower chamber, containing the filter,

is accessible through the filter doors. Where the doors are bolted to the heater-body, the shell is suitably reinforced, the faces being machined to insure a tight joint.

The heater has a doubly-inclined bottom to facilitate thoroughness in draining, and is amply strengthened for the pressures obtaining in ordinary practice.

Water Supply.—The water supply to the heater is controlled automatically, the valve for this purpose being operated by a series of levers connected to an open copper sink-pan (performing the functions of a float), placed within the heater shell.

By this arrangement a constant water level is automatically maintained within the heater—the amount of water to the heater being increased or diminished, as may be necessary to furnish the required amount of feed-water for the boilers. When the water of condensation, returning from the heating system or other sources of drips, is more than sufficient for the immediate requirements, it is held in the storage space provided for this purpose. An automatic overflow is provided to prevent the heater from filling to a dangerous level.

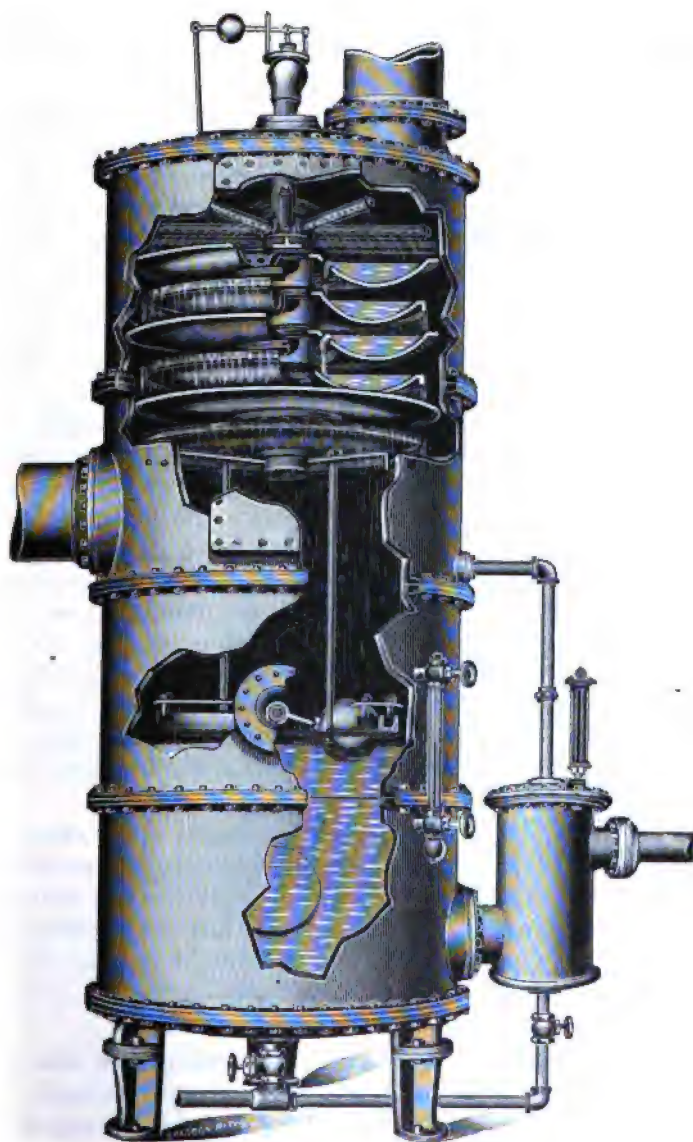
THE PITTSBURGH HEATER AND PURIFIER.

Construction.—In Fig. 102 is shown this well known heater, the construction of which can be clearly seen from the cut.

THE WAINWRIGHT VERTICAL WATER TUBE FEED-WATER HEATER.

Fig. 103.

Construction.—In the construction of a device subject to such great changes of temperature as obtain in a feed-water heater, some provision must be made to ac-

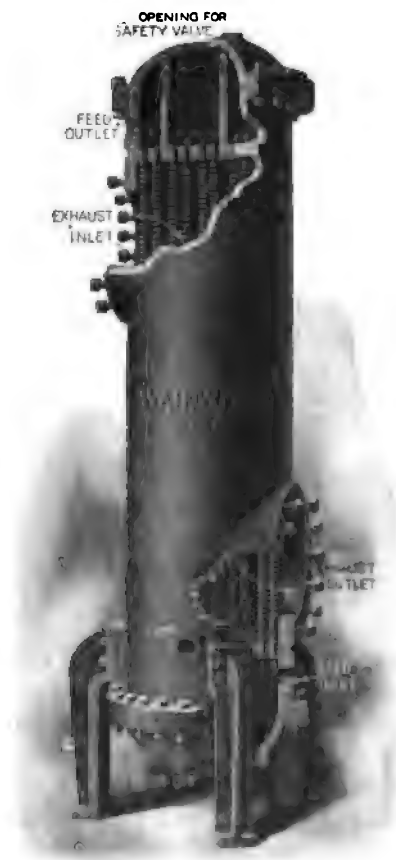


The Pittsburgh Heater and Purifier.
Fig. 102.

commodate variation in the expansion and contraction due to these changes upon various parts of the apparatus. As the heat-transferring medium is preferably of copper, which moves to a greater extent under changes of temperature than the containing shell of iron, it becomes necessary to provide means to accommodate this almost-irresistible force in such a manner as to prevent damage to any of the parts. This has been accomplished in various ways: by screw glands or stuffing boxes at the ends of each tube; by connecting one tube head to the shell by means of a flexible or movable diaphragm, or by providing for this expansion in the tubes themselves. It is this latter method that is employed in the Wainwright Evenflow Heater, the tubes of which are corrugated in such a manner as to take up in the convolutions the movement due to the difference of expansion or contraction between the copper tubes and the cast iron of the shell. Having thus provided for the relief of all interior stresses or strains, it becomes possible to fasten rigidly the tubes into the tube heads in a permanent and substantial manner. In this heater the tubes are fastened at each end into the tube plates by a brass thimble.

This method is extremely simple and effective. There is but a slight and entirely negligible reduction of the free area and no irregular projections to obstruct the flow of water. As a matter of fact the tendency of the water pressure is to increase the tightness of the joint and consequently, within wide limits, the greater the pressure the more secure the fastening.

The tubes are divided into several groups and the water is sent back and forth several times through the heater, and in dividing the tubes there is arranged an odd number of divisions, which makes it possible in a vertical heater to put the feed inlet at the bottom of the



The Wainwright Vertical Water Tube Feed-Water Heater
Fig. 103.

heater and the outlet at the top. This arrangement also allows the exhaust openings to be placed so that the cold entering water meets the outgoing steam, while the heated water, just as it leaves the heater, receives the full benefit of the entering exhaust.

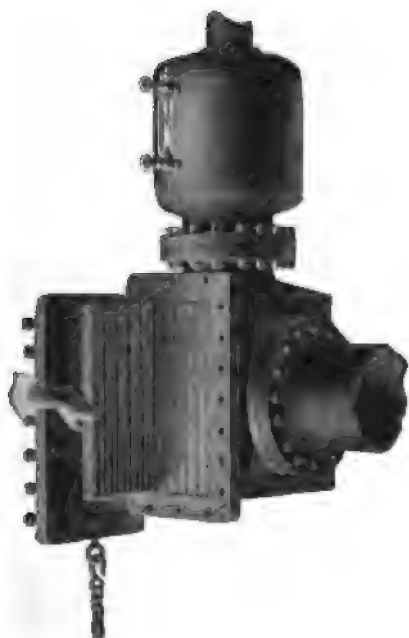
Although the velocity of flow is much greater than in ordinary heaters, it does not even approach a velocity which produces friction enough to offer any objectionable feature. This point has received very careful consideration, and a velocity high enough to produce enormous heat transmission is secured with less friction than is encountered in the feed pipe itself.

THE BUNDEY STEAM AND OIL SEPARATOR.

Fig. 104.

Construction.—Consists of a cast iron flanged body and a catch basin or receiver flanged to the body at the bottom. A nest of baffle or separating plates are placed in the body at right angles to the direction of steam travel. These plates are set staggered. They consist of upright columns with interior channels and cup-like openings to catch the water of condensation. The steam describes a zig-zag or winding course as it passes through this nest of plates from the intake side of the separator to the outlet side.

Operation.—When used as oil separators to extract oil from exhaust steam, the separator is placed as close to the engine as conditions will permit, the intake side being the face or front of the separating plates. As the steam passes through the nest of plates, the oil which it contains, and which is held in suspension, becomes entangled with the plates, is collected by the small cups, and passes down through the channels, dropping into the catch basin or receiver. A tapping in the



Sectional View of the Bundy Steam and Oil Separator.
Fig. 104.

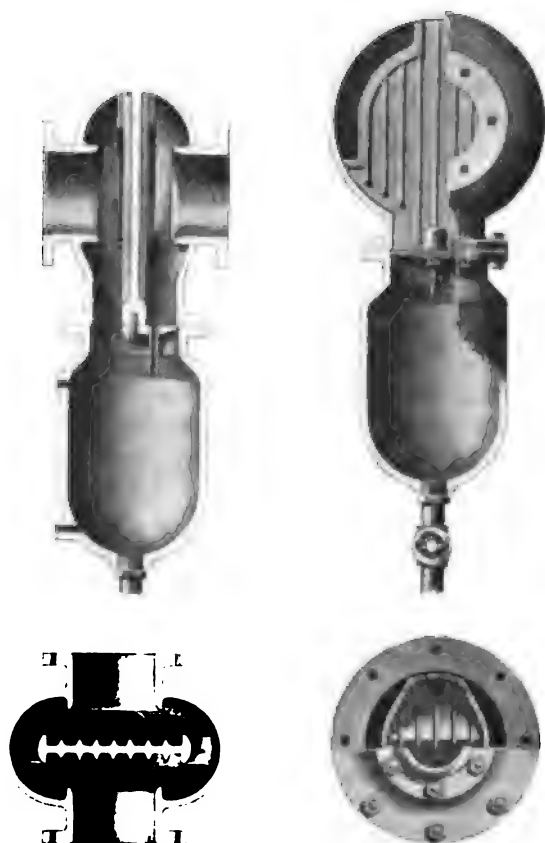
bottom of the receiver permits the connecting up of a waste pipe through which the oil passes off, either by gravity or through a suitable steam trap. This separator is designed to have the side cover plate removable by taking off the bolt heads, swinging it to one side, thus permitting the interior separating plates to be taken out by hand for the purpose of cleaning. It is recommended that these plates should be cleaned about once each fortnight, immediately following the installation of the separator, and at intervals as may be required at other times. Where necessary, separators will be provided with the removable cover plate flanged to the top of the body. In some plants there is not sufficient room to take the plates out from the side, in which event they should be removed from the top.

THE COCHRANE SEPARATOR.

Horizontal and Vertical Forms.

Fig. 106.

Construction.—A single baffle plate facing the inlet opening, presenting sufficient surface for the impingement of all the particles of liquid traveling in the current—ribbed vertically to prevent the side travel of the separated liquid—ports are placed one on each side of the baffle, and these combined, of an area exceeding that of the entering pipe—the opening into well being free and placed directly in front of and underneath the lip of the entering pipe, so that when a large quantity of liquid comes it will pour directly into the well. The well being entirely below the course of the current, and the current not being discharged into it, the liquid taken out will not be disturbed until it rises to the level of the bottom of the main, when the Separator simply be-



The Cochrane Horizontal and Vertical Separator.
Fig. 106.

comes inoperative without the current having the opportunity to drive out or to pick up and carry over the stored liquid. The chamber on outlet side of baffle is closed to well, the drainage for condensation from this chamber being led to well through an internal drip pipe.

The Vertical Form.—Is the equivalent of the horizontal form, modified in design and construction to meet the conditions due to the different direction of the current—viz.: upward or downward flow instead of horizontal—while retaining the same principles of separation.

In the lower left hand corner of above figure is shown a section view of this Separator.

THE DETROIT VERTICAL AND HORIZONTAL CENTRIFUGAL SEPARATORS.

Construction.—In the **Horizontal style** as shown in Fig. 73 the steam enters through the inlet and is deflected downwards by the curved arm, and water and any impurities are thrown partly by gravity and partly by centrifugal force into the well of the separator. The purified steam is drawn off through the outlet from the top of the separator. Drainage is accomplished either by means of an automatic steam trap, or by hand through the outlet valve whenever the water gauge indicates that it is necessary.

The above also applies to the **Vertical style**, the steam entering from above is deflected by the curved partition shown in the sectional cut. This partition has a trough on the lower edge to catch any water that may collect on and run down the sides of the partition. The Vertical Separator is not intended to be operated with an **ascending** current of steam.

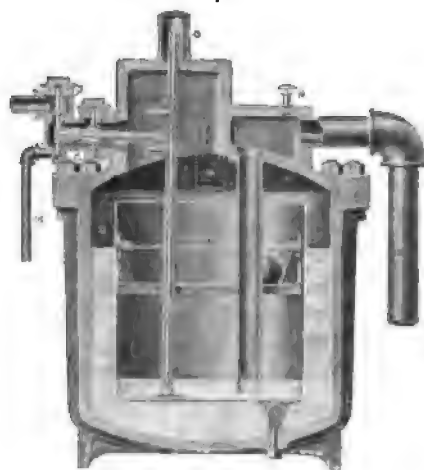
THE ALBANY RETURN STEAM TRAP.

Fig. 107.

Construction.—It consists of a vessel approximately cylindrical in form provided with a closed bottom. A removable bonnet forms a closure for the upper end of the casing and is secured to the same by screw bolts. An open top copper bucket is enclosed in and arranged to tilt within the casing. The bucket is attached to the casing by a hinged joint in such a manner that it will be free to acquire tilting movements when occasion requires. Channeled guides are arranged within the bucket so as to be practically at right angles to the center line of the hinged joint, and in the guides are spherical counterweights, fitted to roll to complete the tilting movement of the bucket by gravitating toward the depressed ends of the guides.

A valve-operating rod is connected by a joint to the bottom of the bucket; the upper end of said rod is fitted to move more loosely in a chambered guide secured to the bonnet. This rod is provided with tappets projecting laterally therefrom and are adapted to take against the inner end of the equalizing valve lever. The tappets are spaced sufficiently apart to afford a degree of lost motion between them and the corresponding end of the equalizing valve lever. The equalizing valve is for the purpose of, on occasions, admitting steam direct from the boiler into the trap cylinder, and is shown connected to the removable bonnet. This same equalizing valve casing contains the small exhaust valve that is useful in some cases, as will be hereinafter explained.

The inlet check valve is the one through which the water of condensation is conveyed into the steam trap, by which communication between the steam trap and



The Albany Return Steam Trap.
Fig. 107.

the system of heating pipes will be controlled at proper times and in a proper manner.

The outlet or discharge pipe will be connected from the steam trap with the water space of the steam boiler, and to prevent a back-flow of water from the boiler into the trap the check valve is placed in the discharge pipe below the water line in the steam boiler. It will be noticed that the discharge pipe extends downwardly into the bucket and reaches nearly to the bottom of the same, so that when the steam pressure is admitted into the steam trap the water contained in said bucket will be forced to flow upwardly through said syphon pipe and thence through the outside discharge pipe and check valve into the boiler.

The air cock on the top of the discharge chamber is to relieve the discharge pipe of any air in first starting the trap in operation. The automatic air valve is adjusted to relieve any accumulation of air from the trap cylinder during its regular operation.

Operation of the Trap in Connection with a Heating System.—In a general way the operation of the trap in connection with a heating system will be: The water of condensation being forced from the coils (or heating surface) through the inlet check valve and opening H (see vertical section, Fig. 2) into the space G between the bucket and outer case, the bucket F will begin to move upwards, caused by the floating power of the water contained between the bucket and the casing when said bucket is tilted sufficiently. The ball weights C will roll on the channeled guides A to the side of the bucket that is adjacent to the hinge joint, thereby providing a sudden impulse in the tilting movement.

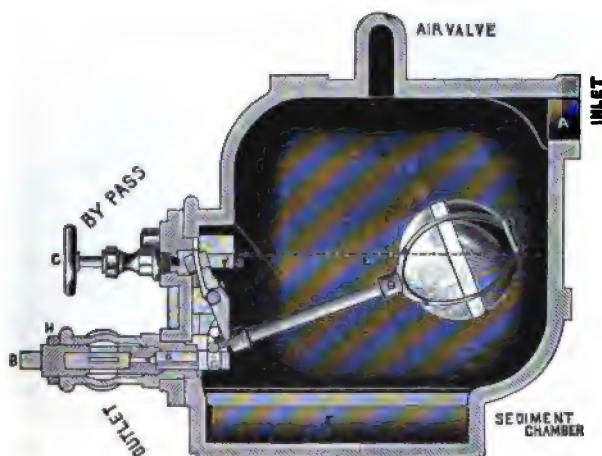
The tilting movement just referred to will, through the action of the valve lever I bring the inlet equalizing

steam valve J on its seat, at the same time through the action of the valve lever it will lift the exhaust valve K from its seat.

The water will continue to flow through the opening H into the space G, and when the space is filled it will flow over the upper edge of the bucket. When the bucket has become nearly filled with water the preponderance of weight causes the bucket to tilt downward, causing the ball weights to roll on the guides to the opposite side of the bucket, thereby providing a sudden impulse downward, and in making such downward movement the upper tappet E on the valve rod B will touch against the inner end of the valve lever I and suddenly open the inlet equalizing steam valve J for the admission of boiler steam. After the pressures have been equalized between the trap and the boiler, the water will begin to gravitate out of the bucket through the syphon pipe D, passing through the pipe D and discharge check valve into the boiler. After the water has been nearly all discharged from the bucket, the water between the bucket and outer case will cause the bucket to move upwards. When said bucket is tilted sufficiently, the ball weights C will again roll to the side of the bucket adjacent to the hinge joint, and as before explained suddenly close the inlet steam valve. After a few seconds, from condensation (or the escape of steam through the exhaust opening M) the pressure in the trap case will become enough reduced so that the condensed water from the system will again enter the space G and will continue repeating the operations as before described.

THE ANDERSON STEAM TRAP.

Construction.—In Fig. 108 is shown a sectional view of this trap, from which can be seen its general construc-



The Anderson Improved Steam Trap.
Fig. 108.

Sizes, Capacity, Etc.

Size Number of Trap	1	2	3	4	5	6	7
Size of Pipe connections, in inches ..	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$
Maximum discharge of condensation per hour in pounds	750	1,200	2,000	2,900	4,000	6,000	12,000
Greatest number of square feet of surface that should be applied.	500	800	1,300	2,350	3,500	5,000	10,000
Greatest number of lineal feet of 1 in. pipe surface that should be applied	1,500	2,500	4,000	7,000	10,000	15,000	30,000
Shipping Weight, in pounds (boxed)	54	67	98	112	145	190	440

valve, and allow discharge of condensation. The level of the condensation when the float is about to lift the valve, is 11 inches above the bottom of the float, which insures the trap to carry at all times plenty of water. The valve will close instantly when the water drops slightly below its level when lifting the valve, thereby causing the float to drop out of contact with the lower lever. The efficient manner in which this trap will handle large sudden floods of water is at once apparent.

It will therefore be seen that by the employment of the Branch System of double levers, that the lifting force or efficiency of the float is increased **five times**, thus making this the most **sensitive** steam trap on the market. The valve is provided with a removable seat, which can be replaced at any time from the outside. The trap is designed to work successfully under all pressures from 1 to 250 pounds, and to deliver water against any back pressure not exceeding 3 pounds less than the pressure of steam in the trap. All traps are furnished with a glass water gauge, blow-off cocks, and are tapped suitable for any size of pipe.

THE BUNDY RETURN STEAM TRAP.

Fig. 110.

Construction.—This return steam trap is governed in operation by the dead weight of the water. Referring to Fig. 110, the machine consists of a cast iron receiving bowl elongated to form a neck, the whole mounted on a frame of cast iron, with a steam valve and an air valve underneath the steam valve, and a horizontal lever, with a balance weight, resting on the ring and extending horizontally over the receiving bowl. Water will flow into the receiving bowl until the weight of the bowl and water combined is sufficient to over-



The Bundy Return Steam Trap.
Fig. 110.



The Bundy Tank Steam Trap.
Fig. 112.

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The Bundy Return Steam Trap.
Fig. 110.



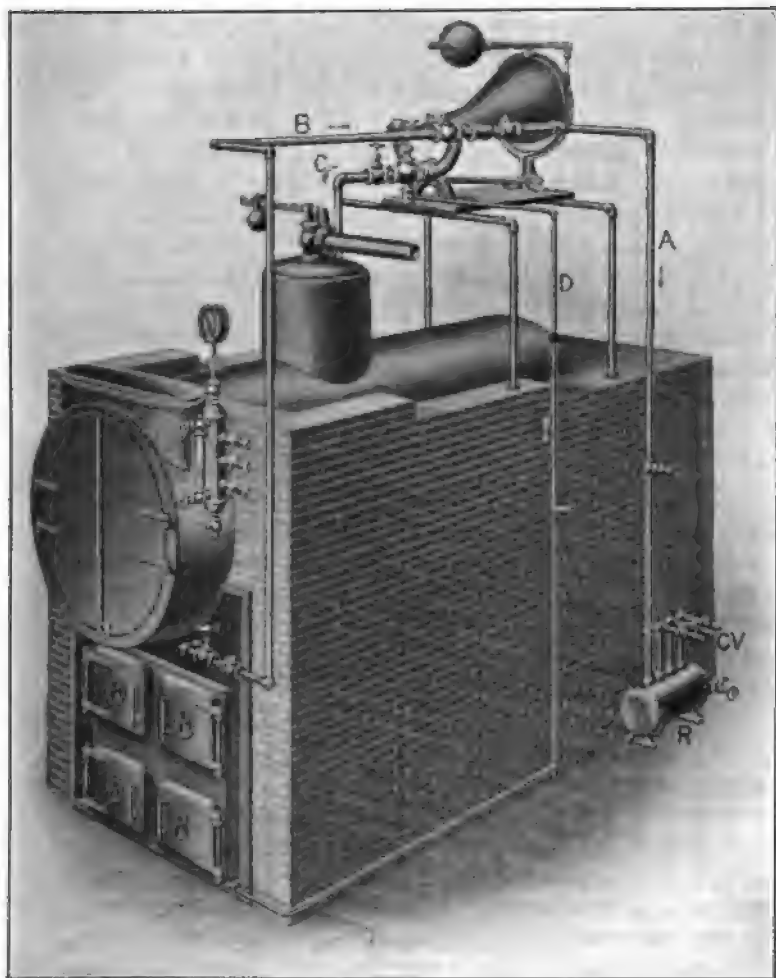
The Bundy Tank Steam Trap.
Fig. 112.

come the weight of the counter-balance and cause the bowl to drop down to the bottom of the ring. By a see-saw motion imparted to the valve stem of the steam valve on the front of the trap, through a ring or metal extension piece which is screwed into the neck of the receiving bowl, and swung on lateral trunnions, the steam valve is opened, admitting live steam from the boiler and permitting the contents of the receiving bowl to pass into the boiler by gravity. The trap itself is placed 3 feet higher than the water line of the boiler and, by equalizing the pressure on the trap with the pressure on the boiler, and with 3 feet head, the water must leave the trap and go into the boiler. The check valves shown are placed respectively, one in the intake pipe and the other in the discharge pipe. When empty the counter-balance weight pulls the receiving bowl back to its original position and opens the air valve, permitting the trap to vent itself of steam and air.

THE BUNDY RETURN STEAM TRAP PLACED OVER BOILER.

Fig. III.

Construction.—From this cut can be seen how an open steam trap, placed over the boiler 3 feet above the water line, can be made to operate successfully. Water of condensation from coils or heating apparatus or steam using machines gathers in receiver R, each intake pipe being fitted with check valves, C V. Condensation passes through pipe A and enters the receiving bowl of the trap through the intake check valve. At discharge, live steam from the boiler enters the trap through pipe C, the water passing from the trap into the boiler through pipe B. When empty, the exhaust from the trap passes through pipe D and is usually discharged



The Bundy Return Trap Placed Above Boiler.
Fig. 111.

into the ash pit of the boiler. An extra check valve and stop valve should be placed in pipe B below the water level of the boiler, as indicated in Fig. 111. Pipe D must be connected into the boiler as far below the water line as possible, preferably into the blow-off of a horizontal tubular boiler. No other feed pipe from pump, or injector, or apparatus of any description, is allowed to be connected into the boiler through pipe B. Pipe C must communicate directly with the steam space of the boiler. There must be enough pressure of live steam or head of water to lift the condensation from receiver R into the trap. One pound pressure is required for each 2 foot elevation.

These return traps are frequently used as "lifting pumps" to elevate water or other liquids from one level to a higher one; also to extract condensation from exhaust pipes of condensing engines subject to vacuum; in other cases as **water meters** to measure and weigh the quantity of water discharged from steam using apparatus within a given time.

THE BUNDY. TANK STEAM TRAP.

Fig. 112.

Construction.—This trap is designed to discharge condensation into the atmosphere, into open or closed receiver, but never directly into the steam boiler. Its operation is governed by the dead weight of the water in precisely the same manner as the return trap. While the trap is discharging, however, the water passes out of the trap through the steam valve, which valve is closed tightly by the return motion of the receiving bowl. Place the trap below the heating coils or steam using apparatus from which it is to receive condensation. Connect the intake pipe into the opening pro-

vided at the top of the yoke. The water will pass through the left hand trunnion and into the receiving bowl. When filled with water, the receiving bowl will drop, opening the steam valve, and the water will pass out through the right hand trunnion, through an interior channel in the right hand horn of the yoke, and through the steam valve. For each pound pressure carried, the trap will elevate the water about 2 feet.

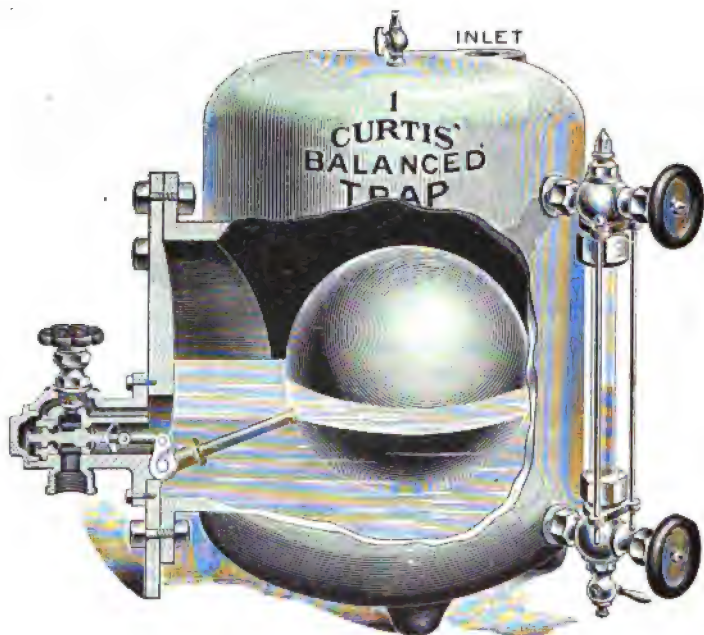
THE CURTIS BALANCED TRAP.

Construction.—In Fig. 113 is shown a sectional view of this trap, from which can be seen its general construction, while below the cut is given its general sizes and dimensions.

THE DAVIS STEAM TRAP.

Fig. 114.

Construction.—This trap is a continuous flow trap designed for general service and suitable for use in connection with either high or low pressure work. All the working parts are attached direct to the cover, and may be removed without disconnecting the pipes. The valves which control the discharge of the condensation, are balanced at every point of their throw and are so constructed that the inevitable dirt, grit and sediment which enter the trap will not interfere with its operation. The inlet and outlet are of the same size, the latter being on the side shunted from the cover. A by-pass valve is provided in the cover. Each trap has a plugged drain hole in the bottom, so that dirt, scale or sediment which accumulates can be removed without opening it. When it is required, this trap can be fitted with a water gauge so that its operation may be observed.



The Curtis Balanced Steam Trap.
Fig. 113.

Sizes and Capacities.

No. 000.	1,000 feet	$\frac{1}{2}$ inch inlet and outlet.
No. 00.	1,500 feet	$\frac{1}{2}$ inch inlet and outlet.
No. 0.	2,500 feet	$\frac{1}{2}$ inch inlet and outlet.
No. 1.	4,000 feet	$\frac{3}{4}$ inch inlet and outlet.
No. 2.	7,000 feet	1 inch inlet and outlet.
No. 2½.	10,000 feet	1¼ inch inlet and outlet.
No. 3.	15,000 feet	1½ inch inlet and outlet.
No. 4.	26,000 feet	2 inch inlet and outlet.
No. 5.	45,000 feet	3 inch inlet and outlet.

THE KIELY STEAM TRAP.

Construction.—In Fig. 115 is shown a sectional view of this trap from which can be seen its general construction, while below the cut is given its general sizes and dimensions.

THE MARCK STEAM TRAP.

Fig. 116.

Construction.—This trap as can be seen by the illustration, has but one movable part, which consists of a hollow tube bent in a crescent shape, the tube being composed of a selected metal, and capable of standing an enormous pressure. This tube is filled with a liquid, which, at 212 degrees Fahrenheit, instantly becomes gas. The expansive force of this gas is so great, that it tends to straighten the tube which causes the valve stem attached thereto to press against the valve seat, thereby closing the trap. The moment the temperature of this tube is less than 212 degrees Fahrenheit, the gas again becomes a liquid, the tube immediately assumes its original position, drawing the valve stem away from the valve seat and opening the trap, and the trap will remain open until the tube is again heated to 212 degrees Fahrenheit or over.

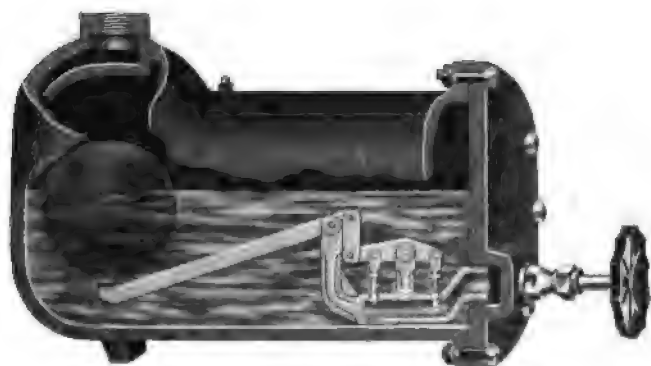
THE McDANIEL STEAM TRAP.

Construction.—In Fig. 117 is shown a sectional view of this trap, from which can be seen its general construction, while below the cut is given its general sizes and dimensions.

THE NASON STEAM TRAP.

Fig. 118.

Construction.—A cast iron reservoir or pot B closed with a cover G provided with two cored passages



The Davis Steam Trap.

Fig. 114.

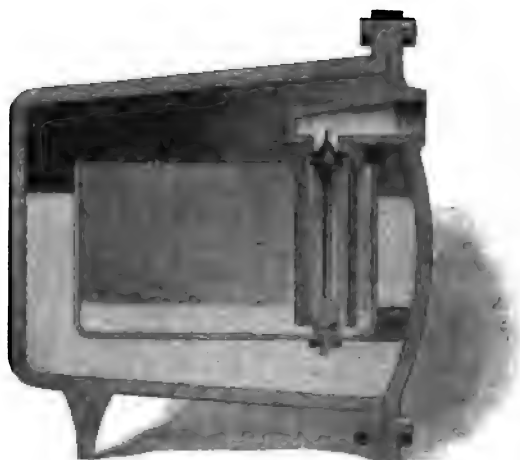
Sizes and Capacities.

Number	00	0	1	2	3	4
Inlet and outlet ins	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2
Capacity, lineal feet of 1-inch pipe....	1,500	3,000	6,500	15,000	20,000	30,000
Weight, lbs.....	25	40	60	80	125	235

contains an open float D which is fitted with a ribbed spindle H for its guidance. A housing or sleeve F is screwed centrally into the under side of the cover G, and within it the spindle H slides smoothly, permitting a short vertical motion. The top of the spindle H is ground flat and its upward movement is arrested by coming in contact with the bronze plug E, having a central opening, the two surfaces thus constituting a discharge valve for these traps.

One of the cored passages in the cover alluded to is for the discharge of water from the trap after passing through the valve E, and the other serves as a by-pass, to permit any large volume of air or water to be blown through, when starting, without going through the discharge valve. Valve K gives entire control of this action.

Operation.—The trap being so placed that the water of condensation flows into it by gravity, the discharge enters at the point marked "inlet" and passing through the cored openings AA into the body of the trap B, a diaphragm C above the float D diverts the water of condensation into the pot or body of the trap B, where, gradually rising, it raises the float D, thereby closing the discharge valve E. Valve K being closed, discharge from the trap is shut off and remains so until the float D becomes nearly filled from the overflow of water into it, when its weight becomes such that it overcomes the tendency of the discharge valve E to remain closed, being held there by steam pressure, and it drops to the bottom, thereby opening the discharge valve E. Acting on the surface of the water, the steam pressure immediately drives it up through the sleeve F (as indicated by arrows), through the discharge valve E, and thence by way of the cored passage to the "outlet."



The Klebey Steam Trap.
Fig. 115.

Sizes and Capacities.

Size Nos.	Size Inlet and Outlet Connections	Capacity Lineal Ft. 1-in. Pipe	Capacity Sq Feet Radiation	Capacity lbs. Water Per Hour
1	$\frac{3}{8}$	4,000	1,300	500
2	1	6,000	2,000	725
3	$1\frac{1}{4}$	10,000	3,300	1,200
4	$1\frac{1}{2}$	15,000	5,000	2,000
5	2	25,000	8,300	3,000
6	3	35,000	11,500	4,000
7	3	50,000	16,500	6,000

When the float D has been nearly emptied it becomes so light that it is again raised by the water surrounding it, thus closing the discharge valve E, and the operation is repeated. The weight of the float D is such that a permanent water seal always remains over the point of discharge into the sleeve F, thus preventing escape of live steam when the discharge valve E is open.

From the above description it will be observed that the valve action is purposely intermittment, which necessitates that it shall be either wide open or completely closed. The life of the valve is thus definitely prolonged and danger of leakage at this point reduced to a minimum.

THE RELIANCE STEAM TRAP.

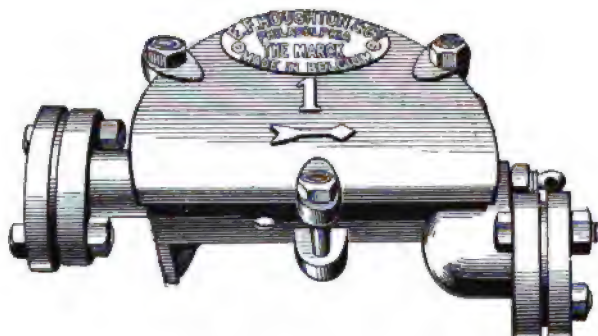
Construction.—In Fig. 119 is shown a sectional view of this trap from which can be seen its general construction, while below the cut is given its general sizes and dimensions.

THE WRIGHT "EMERGENCY" STEAM TRAP.

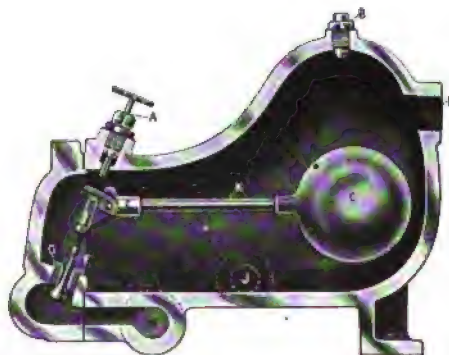
Fig. 120.

Valves at Top.—Three steam-tight outlet valves are employed instead of one. These valves are placed at the **highest point of the trap**, where they are entirely removed from the inevitable grit, scale and sediment, and therefore will not become inoperative from these causes.

In Emergencies.—The action of this trap in emergencies is instantaneous, a feature which renders it invaluable for many uses. The discharge from each of the valves being continuous, is very great—much greater than is possible with an intermittent trap.



The Marck Steam Trap.
Fig. 116.



The McDaniel Improved Steam Trap.
Fig. 117.

Sizes and Capacities—Regular and Low-Pressure Traps.

Trap Numbers	Size of Inlet and Outlet Standard Pipe Size	Drainage Linear Feet of 1-inch Pipe	Equivalent in Sq. Ft. of Heating Surface
12	$\frac{1}{2}$ inch	500	166
13	$\frac{3}{4}$ inch	1,500	500
14	1 inch	4,000	1,333
15	$1\frac{1}{4}$ inch	8,000	2,666
16	$1\frac{1}{2}$ inch	15,000	5,000
17	2 inch	20,000	6,666
18	$2\frac{1}{2}$ inch	25,000	8,333

Operation.—The condensation enters the trap, filling it to about the center and forming a seal of from four to six inches of water at both inlet and outlet, which prevents any possible escape and waste of steam. When thus filled, the float rises and opens the center valve (indicated as valve No. 1 in the enlarged view of valve arrangement, shown on page 378.).

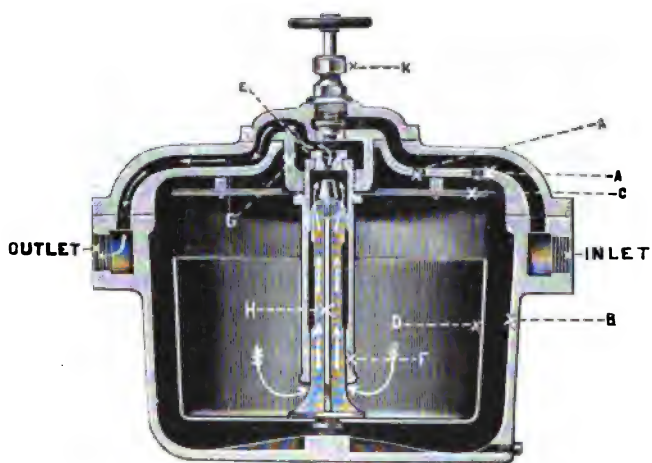
Valve No. 1 is opened slightly, if there is but little water coming in, but widely in event of a sudden inflow. This one valve is equal to the task of taking care of the flow under ordinary conditions, but if the water comes into the trap faster than one valve can discharge it, the water rises in the trap, carrying the float with it and opening valve No. 2 sufficiently to discharge the surplus water, or wide open if necessary. Valve No. 3 is opened in the same manner, providing for the **full capacity of the inlet pipe**, but it rarely happens that the volume of condensation coming into the trap is sufficient to tax the combined capacity of all three valves. Ordinarily, one valve alone is able to do all the work, leaving two valves in reserve for emergencies.

THE HANCOCK INSPIRATOR.

Construction.—In Fig. 121 is shown a sectional view of this inspirator, from which it can be seen that its construction is very similar to that of the ordinary injector. It is one of the earliest types of what is known as the **double tube injector**, and has long been considered as a standard among engineers.

THE PEMBERTHY INJECTOR.

Construction.—In Fig. 122 is shown a sectional view, as well as a full view, of this type of injector. From the illustrations given, its general construction can be clearly



Sectional Cut.

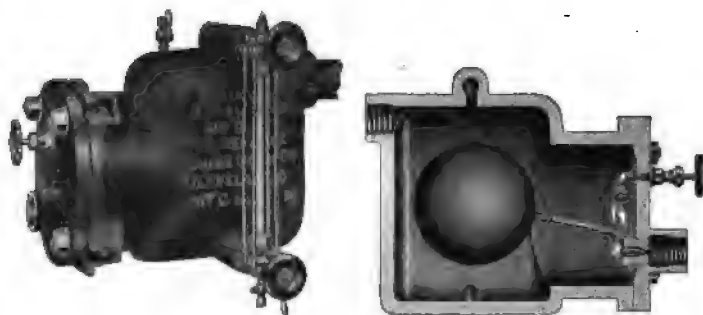


The Nason Steam Trap.
Fig. 118.

seen. It is what is known as an **automatic** injector, by which is meant that when the injector is working and forcing water to the boiler, if the current of water be suddenly **broken** from any cause, such as a sudden jar or jolt as in the case of the traction engine or road roller, the injector will pick up the water and again establish the current to the boiler **automatically**, without the manipulation of any valve or the least attention from an attendant.

Trouble.—In case of trouble with this injector, or any of the usual forms of injectors, the fault is more than probable not with the injector itself, but due to one or more of the following causes, viz.:

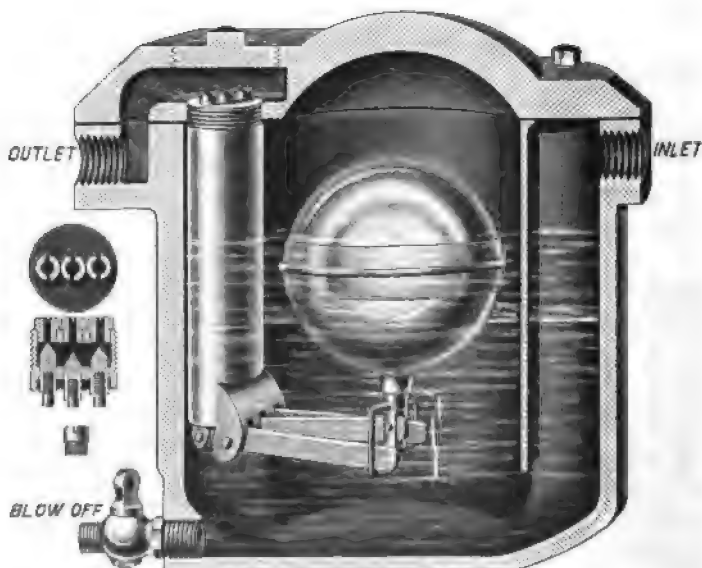
1. Leak in suction pipe (the cause of 60 per cent of all trouble).
2. Supply cut off by strainer getting clogged up.
3. A loose lining inside a hose (common on traction engines).
4. A leak around stem of suction pipe valve (a common cause).
5. Too low pressure for the lift.
6. Too high pressure on long lifts. Throttle steam to get water.
7. Dirt in the tubes, scale, iron cuttings or red lead blown in, or drawn in through steam or suction pipe (25 per cent of all trouble).
8. A bad check valve not lifting enough or not at all.
9. Valve in suction pipe not properly regulated below the pressure where it can be thrown wide open.
10. A loose disc on water supply valve. Get valve on right.
11. Wet steam, foaming boiler, new boilers, full of grease.



The Reliance Steam Trap.
Fig. 119.

Sizes and Capacities.

Size	1	2	3	4	5	6
Size of Connection	$\frac{1}{4}$ in.	$\frac{1}{2}$ in.	1 in.	1 $\frac{1}{4}$ in.	1 $\frac{1}{2}$ in.	2 in.
Discharge per min	4 lbs.	7 lbs.	10 lbs.	25 lbs.	40 lbs.	60 lbs.
Feet of one inch pipe Trap will drain.....	1,000	3,000	4,500	7,500	11,000	16,000

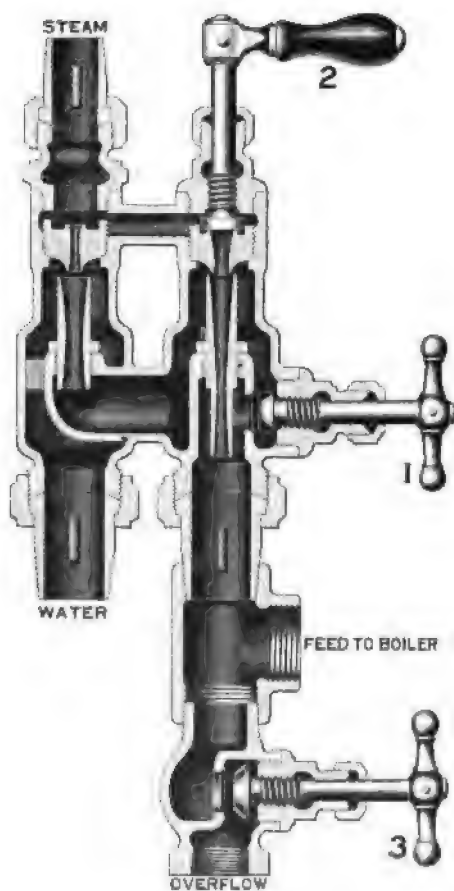


The Wright Emergency Steam Trap.
Fig. 120.

12. Connecting to steam pipe used for other purposes and used at same time.
13. Water supply too hot.
14. Not reading instruction card before connecting injector.
15. Overtaxing injector beyond claims made by the manufacturers.

To Test For Leaks.—When a new “Penberthy” injector fails to work, one of the most frequent causes of trouble is a leak in suction pipe. To ascertain if this is the case, fasten down the overflow valve “P,” by placing a piece of wood or cork under the cap “. ” If possible close the lower end of suction pipe and then turn on steam, which will blow back through suction pipe and appear at the leak if there be one.

Where an Injector Lifts Water But Will not Force to Boiler.—This may be due to a leak in water supply pipe, but is more often caused by some obstruction between the injector and the boiler. It often happens that the end of the feed pipe becomes choked up with lime sediment; we have seen a $\frac{3}{4}$ -inch pipe reduced in this way to $\frac{1}{4}$ -inch. Sometimes the injector is compelled to force through a heater that is old and contains many coils of pipe partially clogged up. If you can, place a steam gauge in feed pipe near injector; if it indicates several pounds over boiler pressure when it breaks, it shows an obstruction. At 50 to 100 pounds pressure the “Penberthy” will force against a pressure of 75 to 135 pounds, showing 25 to 35 pounds over pressure, hence it will force at least a part of the water to the boiler until the obstruction is sufficient to create a back pressure equal to this.



The Hancock Inspirator.

Fig. 121.

THE METROPOLITAN AUTOMATIC INJECTOR.

Fig. 81.

Parts.—

S—Steam Jet.

V—Suction Jet.

C-D-R—Combining and Delivery Tube and Auxiliary Check.

P—Overflow Valve.

O—Steam Plug.

M—Steam Valve and Stem.

N—Packing Nut.

K—Steam Valve Handle.

A—Coupling Nut.

B—Tail Pipe.

X—Overflow Cap.

E—Nut for Stem M.

Construction.—By unscrewing the steam plug O, the steam jet S is removed. The suction jet V is screwed into the injector.

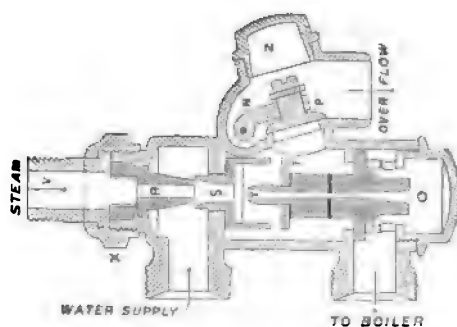
The combining tube C-D is made square on the end so that it can be removed by an ordinary monkey wrench. Be careful that the ring R is not lost; also that it is on the tube in the position as shown in the cuts. Be sure that this tube is not stopped up, and that the small slots and drill holes are clean.

THE DETROIT STOKER.

Construction.—In Fig. 123 is shown a perspective view of this stoker as applied to a horizontal tubular boiler.

THE RONEY MECHANICAL STOKER.

Construction.—In Fig. 124 is shown a perspective view of this stoker as applied to a horizontal tubular



A Sectional View.



The Penberthy Automatic Injector.
Fig. 122.

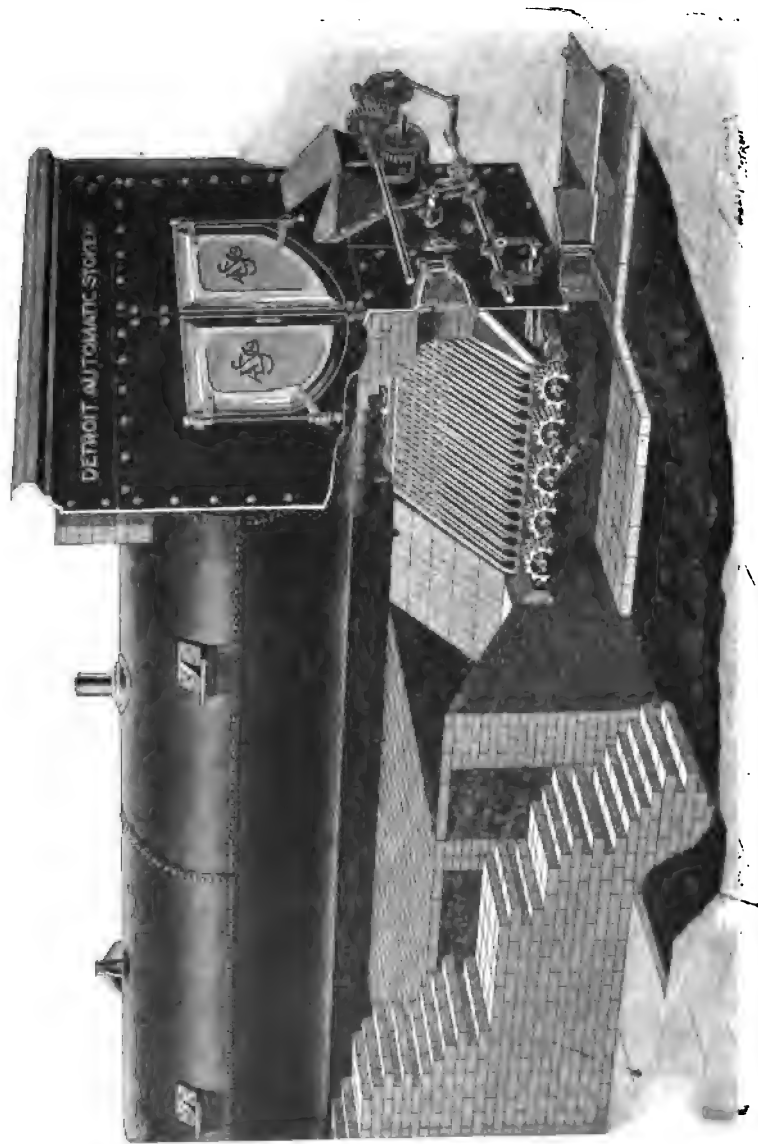
boiler. The coal is fed into a hopper, from which it is pushed by the plate pusher onto the dead plate where it is heated and coked. From there the coke passes to a set of cast iron grate bars, which form a series of steps. Each of these bars is supported at its ends by trunions and is connected by an arm to a rocker bar, which is slowly moved to and fro by an eccentric fastened on a shaft, so as to rock the grates back and forth between the stepped position shown and an inclination towards the back of the furnace, and the grates thus gradually move the burning coke downward. Air for burning the gases is admitted in small jets through holes in the hot-air tiles, and the mixture of gas and air is burned in the hot chambers between the fire-brick arch and the bed of burning coke below.

While the Roney Stoker may be successfully used for burning fine anthracite, it is especially designed for burning all grades of bituminous coal.

The Jones Under-Feed Mechanical Stoker.—The Jones Under-Feed Stoker was invented by Mr. Evan William Jones of Portland, Oregon, and first patented in 1889. It was the first stoker to successfully apply the scientifically correct principle of **under-feed** firing in commercially practicable form.

What is most desirable in a mechanical stoker—simplicity of construction—is embodied in this form of a mechanical stoker. From Fig. 125 is seen that in its internal construction, or more properly styled the portion of the stoker installed **within** the boiler furnace, there are no moving parts whatever exposed to the direct action of the fire. Outside the furnace the construction is limited to a hopper to hold the fuel, and a ram actuated by steam pressure.

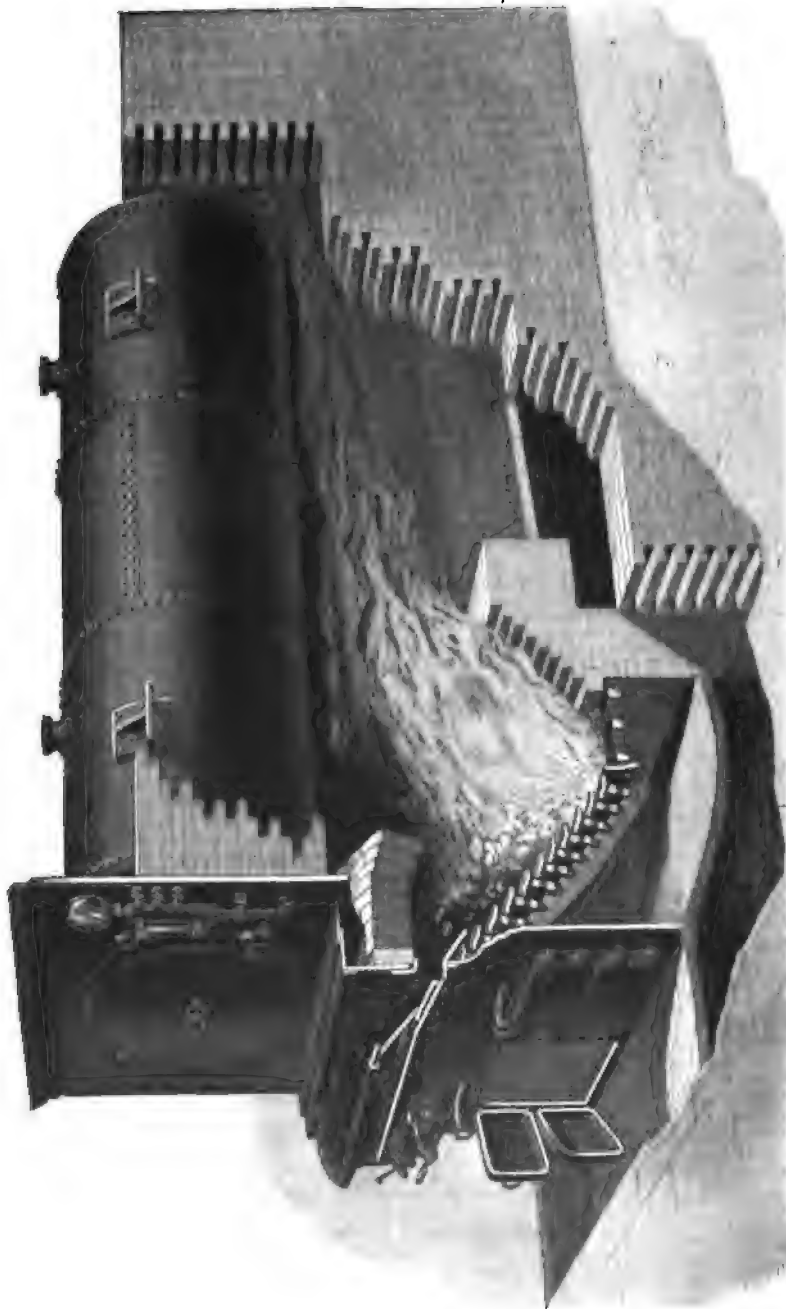
The operation of the stoker naturally follows along the simple line characterizing its construction. The



The Detroit Stoker.
Fig. 123.

coal held in the hopper falls in front of the ram at its withdrawal, and at its forward movement is carried upward into the furnace, the process being expedited and an equal distribution secured within the retort by the plunger rod with shoes attached which in effect is practically an auxiliary ram. As this operation is continued at intervals, the green coal is always forced upward from **beneath**, so that in no event does it reach the fire itself in its green state. A restricted application of the forced draft principle is employed in this method of stoking, air for combustion being delivered by a blower driven by an auxiliary engine or motor. This air is delivered into what is ordinarily termed the ash pit in common practice, but which becomes practically a sealed chamber because the space between the upper edge of retort and furnace side walls is covered with cast iron dead plates. The air needed for combustion escapes through the tuyeres lining the upper edge of retort and enters the fuel at a point between the green coal and that in an incandescent state. It is at this middle stage that a process of coking is going on, the air combining with the gases which are being released by the intense heat above. As successive charges of green fuel enter the furnace this coked coal is gradually elevated to the zone of perfect combustion and the gases passing upward through the fires are consumed. This will account for the thorough manner in which the fuel is burned, thereby securing perfect combustion and a smokeless stack.

A most important feature and one absolutely distinctive of this **under-feed system** is the **automatic regulation** of fuel supply and air supply. By the use of a very ingenious mechanism the steam controls absolutely the amount of fuel admitted to the furnace, and in the same operation, the quantity of air delivered, always



The Roney Mechanical Stoker.
Fig. 124.

porportioning these elements to each other and to the load. For instance, if a suddenly imposed load causes the steam pressure to **fall**, the very fact **increases** the rate of feed of fuel and also increases in proper proportion the supply of **air**. If the reverse is the case and the steam pressure suddenly rises, the rate of feed of fuel is **diminished**, likewise the output of air, this reciprocal relation being maintained under all conditions of operation. The result of this close automatic regulation is that only such an amount of fuel is being burned as is **absolutely necessary**, and in a plant subject to intermittent loads the greatest economy in the production of steam must result because the demand for steam is met immediately and with a less expenditure for fuel.

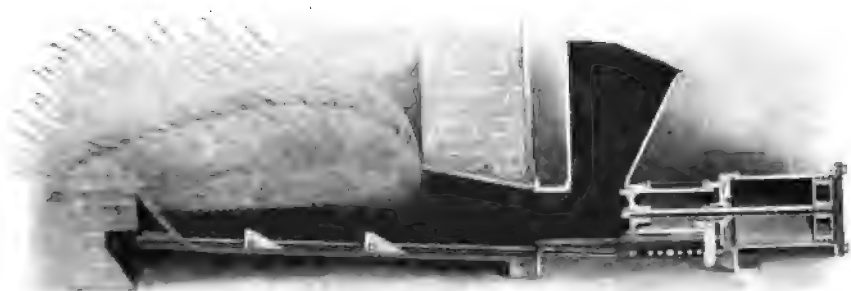
In concluding, the Jones Stoker may be characterized as an apparatus designed to fire a steam boiler most economically, judged from the considerations of saving in fuel, increase in capacity, likewise efficiency, and with considerable reduction in expense for maintenance due to its simple construction.

THE CURTIS DAMPER REGULATOR.

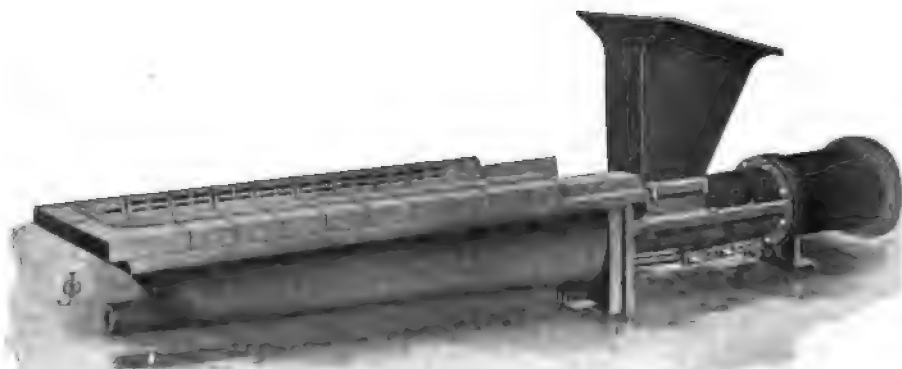
Fig. 126.

Description.—The regulator consists of a composition cylinder, within which is a piston fitted with water packing. The piston rod is connected by a chain, over guide rolls, to the lever of the damper, on which is hung a weight sufficient to overhaul the piston and open the damper, regardless of any ordinary friction.

The motion of the piston is controlled by a metallic diaphragm, which operates the valve, alternately closing and opening the damper, as the boiler pressure increases or diminishes. The regulator is fastened to the wall of the boiler room; the top pipe is connected to



Sectional View.



The Jones Under-Feed Stoker.

Fig. 125.

the boiler, and the lower pipe to the drain, ash pit or heater.

The normal condition of the damper is to be wide open, the weight holding it in that position. To operate it, a given load—say 60 pounds to the inch—is produced on the regulator diaphragm by screwing the handle in. When the pressure in the boiler reaches 60 pounds it lifts this load, and permits steam to enter the space over the piston, slowly pushing it down, and closing the damper. When the boiler pressure falls below 60 pounds the valve closes, and the pressure, passing from the top to the bottom of the piston, puts the piston in equilibrium and allows the weight, slowly settling down, to open the damper, thus controlling the pressure at the desired limit.



The Curtis Damper Regulator.
Fig. 126.

CHAPTER XI.

QUESTIONS AND ANSWERS.

Q. What are the two principal requirements in the management of a boiler?

A. The proper **firing** of the boiler, and the keeping it **clean**.

Q. How should a boiler be fired?

A. The fire should be started so as to burn **slowly** at first, gradually heating all parts of the boiler and settings. In this way strains and injury to the metal is almost entirely avoided.

Q. Why should the boiler be always properly filled with water?

A. In order to keep the water in contact with one side of all metal of the boiler exposed to the fire or heated gases. When iron or steel is heated to **more** than 600 degrees Fahrenheit it becomes weaker, and it is therefore necessary to keep water in contact with the metal to prevent it attaining this high temperature.

Q. How is a boiler cleaned?

A. The work of cleaning a boiler consists of removing the hand-hole and man-hole plates, the boiler first being emptied. The mud and loose scale is then scraped out, and the whole interior of the boiler thoroughly rinsed out with a hose. Should the scale be **too hard** to remove this way, it must then be removed with a hammer and chisel, or some other **mechanical** device.

Q. How often should a boiler be cleaned?

A. This depends largely upon the amount of water the boiler is evaporating, and upon the **quality** and **purity** of the water.

Q. What are the principal requirements in the operation of a boiler?

A. Before filling the boiler with water, a careful examination should be made to see that nothing has been left inside of it. The manhole and handhole plates should then be replaced. The boiler should then be filled until the water shows at least half way up in the gauge glass. Then, **and not till then**, should the fire under it be lighted.

Should the boiler be one of a battery of boilers, it should not be cut into service until it has the **same pressure** as the other boiler or boilers. The stop valves should be opened slowly in order to avoid any sudden change in temperature and excessive expansion in the piping. When the boiler or boilers have been cut into service, the feed water for same should next be carefully regulated. Shortly before shutting down for the night, the boiler should be filled to the **top** of the water glass, so as to allow for evaporation or any leakage during the night.

Q. What is meant by priming?

A. It is the water in the boiler being carried over into the steam pipes and thence to the engine.

Q. What are the most common causes of priming?

A. They are (1) insufficient boiler power; (2) defective design of boiler; (3) water carried too high; (4) irregular firing, and (5) sudden opening of stop valve.

Q. What is foaming of a boiler.

A. It is water which is carried over from the boiler the same as in priming, but it is due entirely to the condition of the water. The water does not **lift** in foaming as it does in priming, but simply **foams over**, due to the dirt or grease contained in it.

Q. What is the **only effective** prevention of foaming?

A. The use of **pure** water.

Q. How often should a boiler be inspected, both externally and internally?

A. At least **once** every year by conscientious and competent officials.

Q. What are the two principal ways of inspecting a boiler?

A. By the **hammer** test, and by the hydrostatic test.

Q. How is the hydrostatic test applied?

A. The boiler is filled full of water and pressure applied by means of a pump, which pressure should be considerably more than the working pressure carried on the boiler.

Q. Why is it necessary that only the pressure required for safety be placed upon the boiler?

A. In order to avoid **straining** the plates.

CHAPTER XII.

BOILERS FOR HEATING PURPOSES.

No branch of engineering has made as rapid strides in the last few years as sanitary engineering, which requires a thorough knowledge of heating and ventilation.

Steam and Hot-Water Heating.—The steam and hot-air furnaces with their expense, dirt and inconveniences, have given way to steam and hot-water systems of heating, affording a luxury to the rich and poor alike which was formerly unknown.

The various systems of heating by steam may be classed: (1) **high-pressure** systems; (2) **low-pressure** systems; (3) **vacuum** or **exhaust** systems.

Under the class of high-pressure systems are all systems that require for heating a greater boiler pressure than 15 pounds per square inch; in the second class are those that operate between 15 pounds boiler pressure and the atmospheric pressure, while in the third class are all systems that work at a lower pressure than the atmosphere; that is, require a partial vacuum for their successful operation. Each of these systems in turn may be subdivided into: (1) the one-pipe system; (2) the two-pipe system; (3) the two-pipe system, with separate return risers; (4) the overhead main, or drop-supply system.

These subdivisions are further subdivided into gravity return systems and forced return systems.

In the **gravity return system** the condensation flows back to the boiler by gravity. To operate this system it is therefore necessary that the full boiler pressure be carried on the entire heating system, which is unsafe and impractical, and it therefore is not much in use.

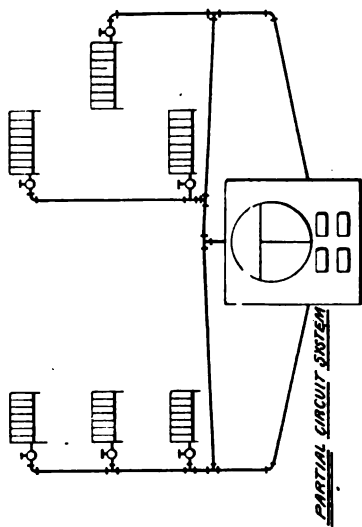
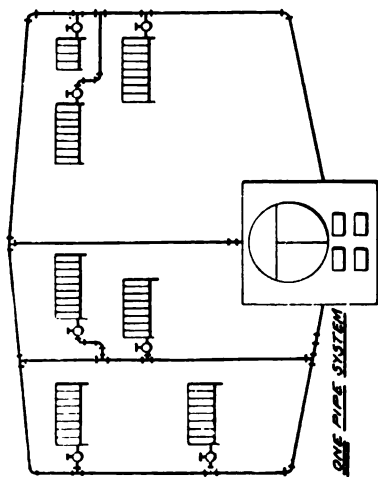
In the **forced return system** the condensation is forced back into the boiler from the return mains of the system by the use of a pump, steam trap or steam loop. To operate this system a reducing valve is necessary, which valve is placed on the steam supply pipe to the system. This system is most generally used, having the advantage of both safety and economy.

The main difference therefore between steam-heating systems, is the method of returning the condensation to the boiler.

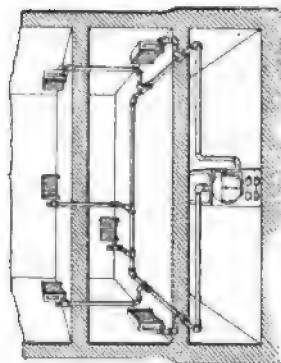
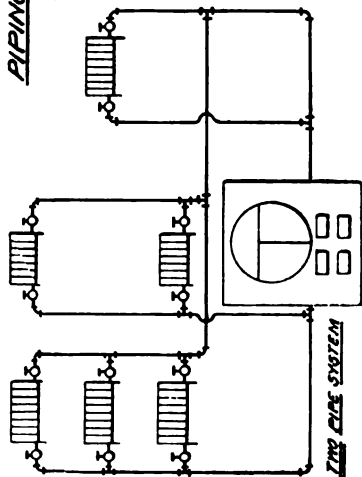
One-Pipe System.—This system, as shown in Fig. 127, is the simplest form of heating systems, and is the system now universally used, when the building or the space to be heated is not too large. The steam from the boiler is carried to the risers through one pipe, the condensation flowing back through the **same pipe**, thereby causing the steam and condensation to move in **opposite** directions, which is a disadvantage, as the steam becoming wet, may cause a "water hammer." With proper installation, and by keeping all valves wide open, this can be avoided.

Two-Pipe System.—This system, as shown in Fig. 127, has two connections for each radiator, one serving as an inlet for the steam and the other as an outlet for the water of condensation, the steam passing through one pipe and the water flowing back to the boiler through the return pipes. In this system the steam and water are carefully **separated**, and the circulation is therefore much better in this system than in the one-pipe system. The principal objection to it, is its **first cost**.

The Separate Return System.—The only difference in this system from the ordinary two-pipe system is that



PIPING FOR STEAM HEATING SYSTEMS.



One-Pipe and Two-Pipe Heating Systems.
Fig. 127.

each radiator is provided with its own separate return pipe.

The Drop-Pipe System.—In this system the steam supply passes through a riser direct from the boiler to the highest point of the system. The radiators are connected to the steam supply pipe with single pipes, the same as in the one-pipe system; but in this system the steam and condensation move in the same direction.

Exhaust or Back-Pressure System.—This system, as shown in Fig. 128, is a **low-pressure** system, having the great economical advantage of permitting of the utilization of the exhaust steam from engines and pumps, which would otherwise go to waste.

The steam-heating main is connected to the exhaust pipe from the engine or pump, also to a live steam pipe from the boiler. This live steam when used is made to pass through a pressure reducing valve, which reduces the pressure to the amount required for the heating system. Should the supply of exhaust steam become excessive, the excess will escape by the opening of the back pressure valve and its discharge into the atmosphere. When the engines or pumps are stopped the steam in the heating system is prevented from passing backwards and filling the same with water, by the use of a check valve. The relief valve is set to blow off at a pressure of about one or two pounds higher than that maintained by the reducing valve. The safety of the system depends on the proper working of this relief valve.

As exhaust steam at 5 pounds gauge pressure contains 971 B. T. U., the merit of this system can at once be seen.

This system is in universal use for heating large

office buildings and entire business districts where access can be had to **steam power plants**.

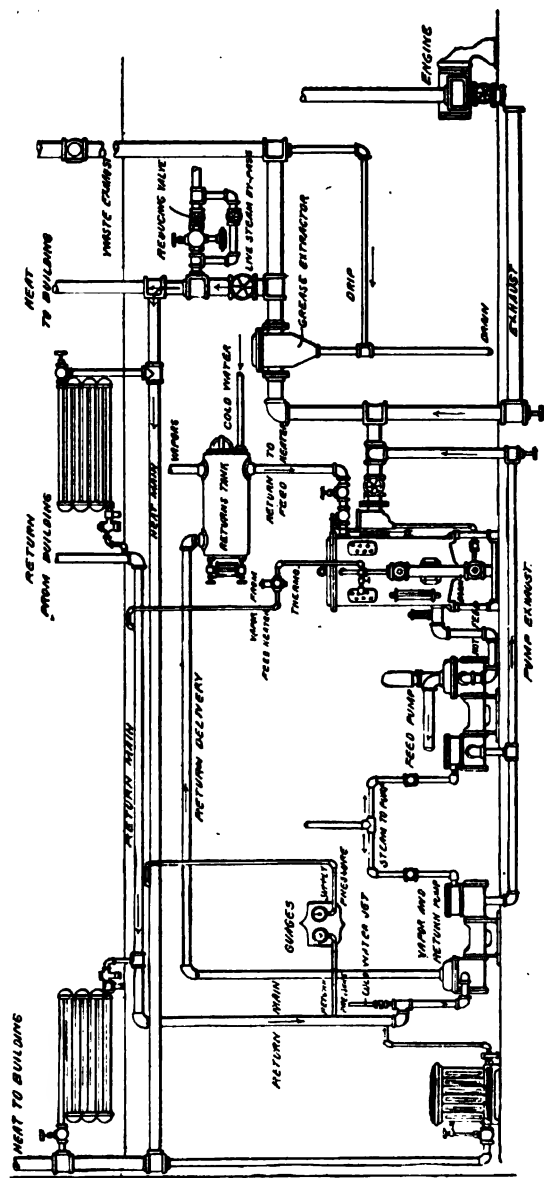
The Vacuum System.—This system differs from the exhaust system just described in that its operation causes no additional back pressure on the engine or pump, but removes at least a part of the back pressure from same, as a **vacuum** is constantly maintained on the returns. This further permits this system to be operated either as a high or low pressure system, and to secure its steam supply from any source, either as exhaust or live steam.

Generally, the system is operated with **exhaust steam**, a two-pipe system being used. The returns are connected to a receiver, which collects the air and water in the system. To this receiver is connected a vacuum pump, which removes all the air and water in the system, and maintains a vacuum at any desired degree. This pump only removes the air and water from the system, which are discharged into an open tank, permitting the air to escape, and the water remaining is pumped back into the boiler, using an ordinary feed pump for this purpose.

The **thermostatic** valves which are placed on the return end of each radiator to open automatically when water or air passes, are made to close when steam begins to pass.

With this system steam can be used at a temperature as low as 140 degrees Fahrenheit, and at the same time the capacity of the engine to do work is increased. As the temperature of the steam used in this system is lower than in other systems, the radiators must be proportionately larger.

The Webster Vacuum System, which is shown in



The Webster Vacuum Heating System.

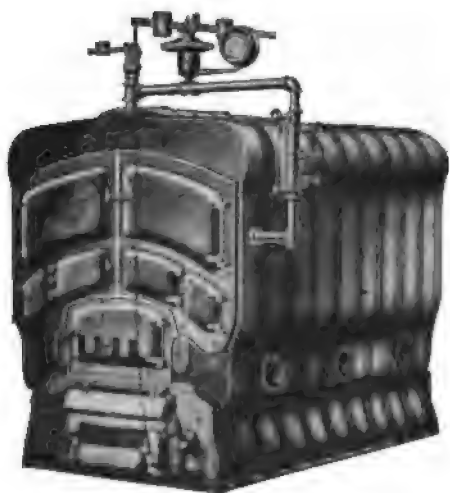
Fig. 129.

Fig. 129, is one of the best vacuum systems on the market.

Hot-Water Heating.—Hot-water systems are very similar to the steam systems described, except that **hot water** flows through the pipes and radiators, instead of steam. The hot-water system has the great advantage, though, of the ease of **regulation** of the temperature. With a steam system, it is necessary to regulate the temperature by turning on or off the steam **entirely**, which causes either too high or too low a temperature, unless operated carefully.

With a hot-water system the radiators can be kept turned on at all times, the regulation of temperature being secured by varying the **temperature** of the **water** flowing through them. There are two distinct hot-water systems of circulation employed, one depending on the difference in temperature of the water in the outlet and return pipes, called **gravity circulation**; and the other called the **forced circulation** system, in which a pump is employed to force the water through the mains. The first, or "gravity circulation" system, is used for dwellings and small buildings, and the latter system for **large buildings**, and wherever there are a **long run** of mains. For the first system usually a sectional cast iron boiler is employed, although any type of boiler may be employed. In the second or "forced circulation" system, a heater to warm the water, and a centrifugal or rotary pump is used. Fig. 130 is a type of a sectional cast iron boiler. These boilers should be regularly inspected, for no boiler under pressure, however small that pressure may be, is perfectly safe. The only perfectly safe boiler is one which has no fire under it.

A system for hot-water heating costs more to install than a steam-heating system, owing to the differ-



The Ideal Sectional Boiler for Steam Heating.

Fig. 130.

ence in the expense of the **radiators**, and the **larger piping** that is required, but is more economical.

Indirect Hot-Water System.—In this system the air to be heated is taken from a cold air box in connection with the space beneath the heater. This air, in passing through the spaces between the sections of the heater, and becoming warmer, rises to the rooms above through registers placed in the floors or walls, as most convenient.

Forced-Blast Heating.—This system of heating is used for the warming of factories, schools, churches, or any large building where good ventilation is also desired. The air to be used for warming is either drawn or forced through a heater of special design by a **fan** or **blower** and discharged into ducts which lead to registers placed in the halls to be heated. By means of a by-pass damper, so placed that only part of the air will pass through the heater and part around and over it, the proportions of cold and heated air may be so adjusted as to give the desired temperature to the air entering the halls.

Radiators.—Fig. 131 shows the general form of a radiator for direct heating which is similar for steam and hot-water heating, the one difference being that the sections are connected at the top as well as the bottom for hot water, but connected **only at the bottom** for steam. A cap is used to close the ends of the top connection, and by this the difference in the two radiators can be seen at a glance. Radiators for **indirect heating** differ in construction so as to permit the cold air to be heated, to be freely drawn or forced around or through them.

Radiation Surface.—The following will show the proportionate radiation surface to the cubical contents



The American Radiator for Steam Heating.

Fig. 131.

of the room to be warmed, where direct radiation is used:

Bathrooms and living-rooms with three exposed walls and a large amount of glass surface, require an allowance of 1 square foot for each 40 cubic feet.

Bathrooms and living-rooms with two exposed walls and a large amount of glass surface, require an allowance of 1 square foot for each 50 cubic feet.

Bathrooms and living-rooms with one exposed wall and an ordinary amount of glass surface, require an allowance of 1 square foot for each 60 cubic feet.

Sleeping rooms require an allowance of 1 square foot for each 60 or 70 cubic feet.

Halls require an allowance of 1 square foot for each 50 to 70 cubic feet.

School rooms require an allowance of 1 square foot for each 60 to 80 cubic feet.

Churches and auditoriums having large cubical contents and high ceilings, require an allowance of 1 square foot for each 65 to 100 cubic feet.

Lofts, workshops and factories require an allowance of 1 square foot for each 75 to 150 cubic feet.

For indirect radiators allow at least 50 per cent more surface.

No heating system can be successfully operated without **steam traps** of sufficient capacity to remove all the condensation.

The water of condensation in a steam-heating system is led into the steam trap and thence allowed to flow through a "cooling coil," before being discharged into the drainage system.

Under ordinary conditions for steam heating, one horse power will heat in brick buildings 15,000 to 20,000 cubic feet; in brick stores, 10,000 to 15,000 cubic feet;

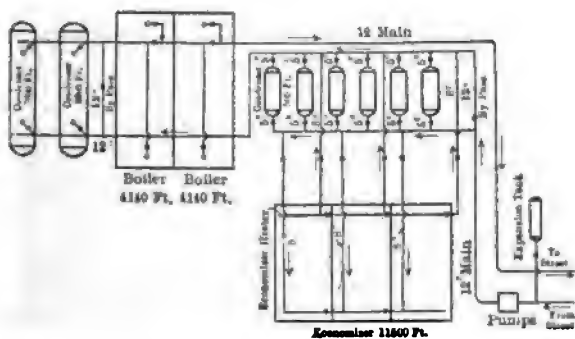
in brick dwellings, 10,000 to 15,000 cubic feet; in brick churches, brick shops, etc., 8,000 to 12,000 cubic feet; wooden dwellings, 8,000 to 10,000 cubic feet.

Where the exhaust steam is used in connection with a hot-water system, the water to be warmed is heated by the steam in large heaters, similar to feed-water heaters, and circulated through the mains by means of centrifugal pumps.

Central Station Heating.—Where large districts are to be heated, a central heating station becomes necessary, the steam or hot-water mains from same being laid **underground**, through the streets. Both steam and hot water are used for this character of heating, but it is generally admitted that where the district is large that the **hot-water** systems are the best as there is much less loss from condensation in the mains, and the temperature can be much better regulated. As the exhaust steam from some large plants is generally used in connection with either of these systems, the central heating plant should be located as near as possible to it, and the exhaust steam conveyed through an underground duct in as direct a path as possible. The equipment of the station depends largely upon the extent of the district to be heated, it being usual to allow for steam heating 1 square foot of boiler heating surface for supplying 10 square feet of radiating surface, or one boiler horse power to each 120 to 200 square feet of radiating surface, depending upon whether steam or hot water is used.

Fig. 132 shows a complete installation of a central station heating plant.

Insulation and Cost.—The **underground distributing system mains** in either system must be properly insulated, or the loss by condensation will be very great.



Central Station Heating Plant.

Fig. 132.

Fig. 133 shows a form of insulation which has proved quite satisfactory. Using this insulation, the hot water has been sent out through a two-pipe balanced system six and one-half miles or thirteen miles out and returning, with a loss of only 30 degrees, the water being sent out at a temperature of 170 degrees, and returning at 140 degrees.

SPECIFICATIONS AND CONTRACT FOR A LOW PRESSURE STEAM HEATING PLANT.

Boiler.—Furnish complete and set up in basement one steam boiler having a heating capacity equal to 3,400 square feet of radiation.

Foundation.—Boiler to set on good substantial foundation of hard burned brick laid in Portland cement, or to have concrete foundation of proper dimensions to suit size of boiler.

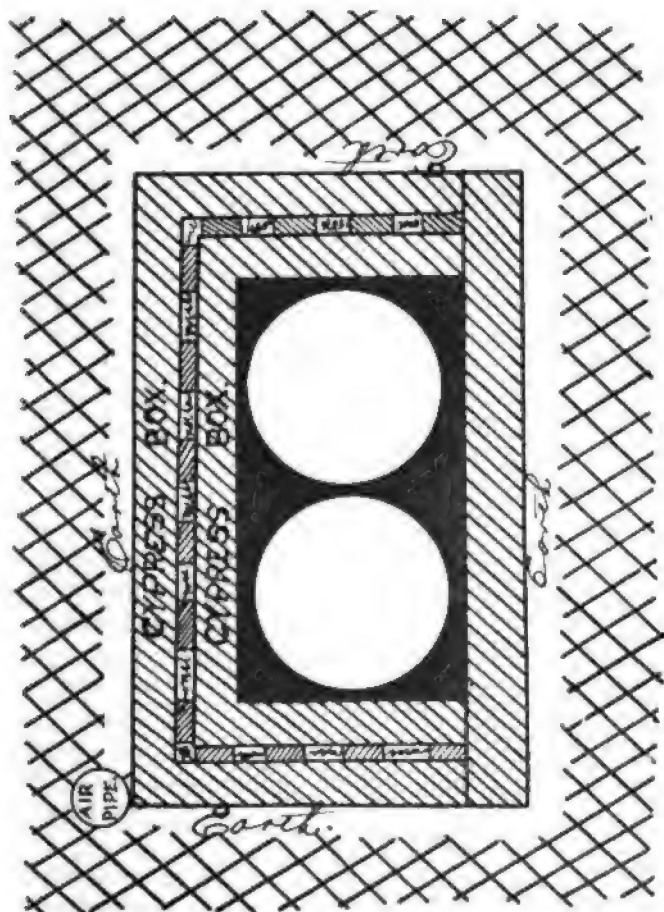
Smoke Connection.—Furnish and erect smoke connection from boiler to chimney of number iron of sufficient size to insure a good draft with necessary damper and check door.

Grate Bars.—Furnish and set with boiler a full set of improved grate bars.

Trimnings.—Furnish and connect to boiler all necessary fixtures and trimmings called for by manufacturer of boiler, consisting of safety valves, low pressure steam gauge, combination body with connections to boiler, suitable blow-off valves, feed water and check valve.

Firing Tools.—Furnish and set with boiler a full set of firing tools consisting of poker, hoe, slice bar, flue brush and scoop shovel.

Automatic Damper Regulator.—Set up and properly connect with boiler, one automatic damper regu-



Insulation for Two-Pipe Heating System.

Fig. 133.

lator or diaphragm, to be placed on top of boiler and shall be connected to draft door and check draft in smoke pipe with iron chain for the admission of the proper quantity of air to the fire to govern the steam.

System of Heating.—The system of heating will be that known as the Low Pressure Gravity System, all water of condensation to be returned to boiler by gravity.

Size of Mains.—The size and general run of all basement and riser pipes to be such as to be best adapted to suit the location of the radiators. All connections to radiators, branch supply pipes and the entire piping throughout shall be ample in size to insure a rapid and noiseless circulation of steam throughout the entire apparatus.

Securing Pipe.—All piping shall be constructed with proper provisions for expansion and contraction, all basement pipes to be secured on neat cast iron expansion hangers placed at proper intervals.

Insulation.—Where pipes pass through partitions in basement, there shall in each case be provided wrought iron sleeves one size larger than the pipe they are used on and come flush with walls; where pipes pass through floors they must be provided with wrought iron sleeves of proper length and size, same to make a neat finish at floor and ceiling.

Floor and Ceiling Plates.—All pipes on riser and radiator connections and all pipes in finished parts of basement, shall be provided with neat cast iron floor and ceiling plates of the most approved pattern.

Pipe and Fittings.—All pipes used in the erection of this work shall be of the best make and of standard weight and sizes; all pipe over 1¼ inches in size to be lap-welded. All fittings used shall be fine grained grey cast iron with clean cut taper threads.

Materials and Workmanship.—All materials entering into the construction of this apparatus, whether specified or not, shall be the best of their respective kinds, and all put together by skilled mechanics under our immediate supervision.

Valves on Radiators.—Each radiator shall be operated by but one valve, which shall be of the best steam mental, extra heavy, with Jenkins disc, to have Union Coupling Joint, to be heavy nickeled all over and have polished hardwood handles.

Air Valves.—Each radiator and end of heating main shall be provided with an automatic nickel plated air valve guaranteed not to throw water.

Valves and Check Valves.—All globe, gate and check valves 2 inches in size or smaller to be made of extra heavy steam metal; all valves 2½ inches in size or larger to have iron body with brass trimmings.

Finish of Radiators.—All radiators are to be finished in colors selected by architect or owner. All exposed pipes above cellar to be finished same as radiators; all pipes in basement and boiler room to be painted with best Asphaltum varnish.

Requirements of Owner.—Owner shall provide opening for the admission of boiler and space in boiler room for the erection of same. Owner to provide water and sewer connection in boiler room near boiler and chimney of sufficient size.

Cutting and Repairing.—We will do all necessary cutting and repairing for the admission of our work, and remove all debris connected with our work.

Guarantee.—We guarantee to heat all rooms and halls specified to be heated as stipulated in schedule of radiation to 70 degrees when the thermometer is zero on the outside with a pressure not exceeding 5 pounds.

We further guarantee to fill the whole system with one pound of steam on boiler, and the working of the apparatus to be absolutely noiseless and the apparatus to be free from all leaks or imperfections.

Radiation.—The radiating surface shall consist of ornamental cast iron radiators of most approved design, and shall be placed in position for obtaining the best results in numbers, sizes and heights. Total amount of radiation to be not less than 2,415 square feet divided into 75 radiators.

SPECIFICATIONS FOR A COMPLETE CENTRAL HEATING PLANT.

General.—These specifications are intended to cover a complete heating plant in all details, and if, in these specifications, anything is needed to make the plant complete in accordance with the intent hereof, then in that case it shall be furnished by the contractor without any further charge to the purchaser.

Definition.—Whenever the word "purchaser" is hereinafter referred to, it shall be understood to mean the Heating Company, of Whenever a "contractor" is hereinafter referred to, it shall be understood to mean the of Whenever a classification hereinunder is specified and no mention is made of either the purchaser or contractor, it shall be understood that the contractor is to do the described work.

Real Estate.—A piece or parcel of land shall be furnished by the contractor to the purchaser, the same to be located

Power House.—Upon the above described piece of real estate there shall be installed a substantial brick

power house by the contractor, the same to be of neat design and suitable for the purpose of building therein the necessary appurtenances for a complete central station heating plant.

Boilers.—There shall be installed a sufficient amount of heating surface, the same to be divided into the number of units adapted for the work, sufficient heating surface, together with exhaust steam which is to be furnished to the plant by the company from the power house of the railway and electric company, sufficient capacity to handle at 10 degrees above zero square feet of radiation, the same being operated with a hot water circulation. The above described boilers shall be of the or some other water tube type equally as good. They shall be equipped with shaking grates and the necessary tools for the firing of the same.

Smoke Stack.—A smoke stack of the proper diameter and height shall be installed for each battery of two boilers. Same shall be carried from the top of the boiler settings and maintained by a guy stub set in the proper position.

Boiler Feed Pumps.—There shall be furnished two bronze fitted boiler feed pumps; each pump should have sufficient capacity to handle the entire plant with a piston speed not to exceed 100 feet per minute.

Feed-Water Heater.—There shall be furnished a feed-water heater and purifier of sufficient capacity to furnish boiler feed water for the number of boilers that will be necessary for the operation of the plant in question. It shall also be of sufficient size to purify the water used in the heating system.

Circulating Pump.—There shall be furnished two bronze-fitted special designed hot water circulating

pumps, to be used for the purpose of circulating the water in the heating system. They shall have a capacity of not less than fifteen gallons of water each per minute. They shall be erected upon the proper foundations by the contractor and equipped with automatic governors.

Placing, Regulating and Receiving Pumps.—There shall be furnished the necessary pumps, the same erected upon foundations and equipped with an automatic governor to relieve the apparatus from condensation, maintain the necessary vacuum on the system, and to make the plant complete in all its details.

Vacuum Pumps.—There shall be installed a vacuum pump of sufficient capacity, the same to be bronze-fitted throughout, to handle the exhaust steam which is to be received from the plant. Same shall be erected complete upon foundation to be furnished by the contractor.

Condensers.—There shall be furnished two condensers, being of feet size. The same shall be delivered and erected complete upon foundations furnished by the contractor.

Pipe Connections.—The contractor shall furnish all necessary valves, fittings, pipe, labor, etc., so as to connect up all the above described apparatus so as to be complete in all its details and in a good and workmanlike manner.

Pipe Covering.—After all of the apparatus has been installed and connected, all pipe and fitting shall be covered with an approved pipe covering.

Air Compressor.—There shall be furnished one air compressor, same having a capacity of feet of free air per minute. The same shall be equipped with the necessary regulators, storage tanks, etc.

Gauge Boards.—There shall be furnished one marble gauge board, the same having mounted thereon all the necessary gauges, thermometers, etc., for the indicating of the proper working of the system.

Pipe Line.—The pipe line to be laid in the various streets in the city of shall be laid by the contractor and shall consist of the following pipe lines:

..... feet 14-inch main.

..... feet of 12-inch main.

..... feet of 10-inch main.

..... feet of 8-inch main.

..... feet of main which shall be of such average sizes so as to equal the cost of 6-inch main.

Location of Mains.—The mains shall be located in such parts of the streets as found convenient on account of construction conditions. The mains shall be so laid as to have a cover of earth of at least two feet, excepting in such places as obstructions are encountered; then, in that case, the minimum depth from surface of street to top of insulation shall be at least 12 inches.

Materials.—The materials to be used in the construction of the pipe lines in question, shall consist of gum lumber of the proper thickness and lengths, the same to be of a first-class quality.

The pipe shall be of standard wrought full-weight pipe, of the Crane or National Tube Company's manufacture, or something equally as good. All fittings shall be of standard grey iron and true as to weights, etc. The pipe lines shall be protected throughout with a system of valves and expansion joints. Wherever valves or expansion joints are put into the system, they shall be surrounded with a brick manhole with a cast iron top, so as to permit of free access to the same.

The expansion joints shall be so arranged that there will not be any undue strain on any of the fittings in the system.

Service Openings.—Service openings shall be made in the system as needed to provide for the taking off of service connections. They shall average at least one to every 100 feet of main.

Test.—As the street work is installed, it shall be tested, so as to be tight under a pressure of not less than 60 pounds.

Re-Paving.—Whenever any of the lines are laid in streets which have been paved, the pavement shall be replaced in as good a condition as found.

Time of Completion.—The work herein contemplated shall be completed and in full running order by, in accordance with the minimum terms of the franchise.

Finally.—During the construction of the plant the contractor shall furnish all the engineers and superintendents necessary for the complete building of the plant, together with the measuring of the buildings and making of contracts for the heating of the buildings. As soon as the plan is ready for operation, the purchaser shall measure all buildings and make all heating contracts and shall provide the necessary attendants for the operation of the plant, together with all the necessary fuels and materials for the proper operation of the same. The contractors shall furnish for a period of thirty (30) days, if necessary, an expert to instruct the superintendent of the heating company in the proper management and operation of the plant.

Guarantees.—The contractor guarantees the plant shall be complete in all details and operate successfully as a central station heating plant, and any defects de-

veloping in one year shall be replaced by contractor without expense to purchaser.

System.—The system shall be what is known as, and shall be built under the direction of

RULES FOR JANITORS AND FIREMEN HAVING CHARGE OF LOW PRESSURE STEAM HEATING BOILERS.

Hartford Steam Boiler Inspection and Insurance Co.

1. **Getting Ready to Start.**—The attendant should see that all joints are properly packed, and that none leak on filling the boiler with water. The gauge cocks, water gauge, and safety valve should be carefully examined that all are free and in good order. All valves in piping and radiators and air valves, should be examined and seen to be in order, and that all necessary packing or repairs have been done.

2. **Condition of Water.**—The first duty of an engineer when he enters his boiler room in the morning is to ascertain how many gauges of water there are in his boilers. Never unbank or replenish the fires until this is done. Accidents have occurred and many boilers ruined from neglect of this precaution.

3. **Raising Steam and Management of Valves.**—All steam and return pipes should be closed before fires are started. When steam has been raised to working pressure, the steam valves should be opened very slowly. After the boiler pressure is established in the pipes the return valves can be opened, allowing the water of condensation to flow back to the boiler. Whenever necessary to shut off at the boiler or any section of heating system, the return or drip valves should be closed first and then the steam valves. In letting on the steam the

supply or steam valves should be first opened and then the return or drip valves. This caution is important.

4. Low Water.—In case of low water, immediately cover the fires with ashes, or if no ashes are at hand, use fresh coal and shut the ash pit and open the fire doors. Do not turn on the feed under any circumstances or tamper with or open the safety valves. Let the steam outlets remain as they are.

5. Feeding.—When necessary to take fresh water the boiler should be fed as slowly as possible to avoid unnecessary contraction and leakage at joints.

6. Gauge Cocks and Water Gauge.—Keep gauge cocks clean and in constant use. Glass gauges should not be relied upon altogether.

7. Safety Valves.—Raise the safety valves cautiously and frequently, as they are liable to become fast in their seats.

8. Safety Valve, Automatic Regulator, and Steam Gauge.—Should the gauge at any time indicate the limit of pressure to which the regulator is adjusted without its controlling the draft, the regulator should be examined and disconnected from the damper or draft door. If the regulator works quickly and well the trouble is in the damper or draft door, and it should at once be cleaned and made to work freely. Should the regulator fail to work, or work very slowly, the pipe connection to the boiler is choked and should be cleaned. See that pressure gauge, regulator, and safety valve agree; in case of difference, notify the company's inspectors.

9. Clean Plates and Heating Surfaces.—Particular attention should be taken to keep plates and parts of boilers exposed to the fire perfectly clean. Also, all tubes, flues, and connections well swept. This is particularly necessary in many types of small heating boil-

ers with large heating surfaces and small heat passages, as they soon foul if neglected. Strict attention to this rule is necessary for full economy and capacity of boilers.

10. Blowing Off.—If necessary to blow down during the season, the fires should be hauled and furnaces and bridge wall cleaned at least two hours before blowing down. Allow the boiler to stand until cool before filling with cold water.

11. Laying up Boilers for the Season.—Haul fires, clean furnaces, and run off the water while hot. Thoroughly clean all heating surfaces at once. Remove hand and manhole plates, dry out water if any remains, and leave the boiler thoroughly clean and dry. Drain all water from return drip pipes. All good systems are provided with drip cocks at lowest point in return pipes for this purpose. During the summer see that no water can drip or moisture collect in or around the boiler.

12. Piping, Radiators, and Settings.—Mark all joints that have shown signs of leakage and need packing; also air cocks and valves and anything that may need repairs before using another season. If repairs are needed to boiler settings see what they are and have them made while boiler is idle.

CHAPTER XIII.

BOILER TRIALS.

Horse Power and Efficiency Tests.—The horse power of a boiler is entirely a measure of **evaporation**, and not of power as the term would lead one to believe.

Unit.—One boiler horse power as has been previously defined, is equivalent to the evaporation of 34.48 pounds of water from and at 212 degrees Fahrenheit or practically $34\frac{1}{2}$ pounds of water per hour, which is the same as the evaporation of 30 pounds of water per hour from feed water having a temperature of 100 degrees Fahrenheit into steam at 70 pounds pressure.

Standard.—It is usual to express the evaporation of the water in the boiler from and at 212 degrees Fahrenheit, instead of from 100 degrees Fahrenheit at a steam pressure of 70 pounds, as this is the **standard boiler horse power** recommended by the American Society of Mechanical Engineers.

Commercial Rating of Boilers.—This society, which is recognized as the **highest authority** on all subjects pertaining to mechanical engineering, further recommended as follows:

“A boiler rated at any stated capacity should develop that capacity when using the best coal ordinarily sold in the market where the boiler is located, when fired by an ordinary fireman without forcing the fires, while exhibiting good economy; and further that the boiler should develop at least **one-third more** than the stated capacity when using the same fuel and operated by the same fireman, full draft being employed and the fires being crowded; the available draft at the damper,

unless otherwise understood, being not less than $\frac{1}{2}$ -inch water column."

Efficiency.—By the efficiency of a boiler is meant the ratio between the heat units utilized in the production of steam, and the heat units contained in the fuel used.

In order to determine the horse power and the efficiency of a boiler, all boilers must be tested under the same set of rules, so that the conditions will be exactly the same.

Code of Rules.—In order to obtain such uniformity, the American Society of Mechanical Engineers appointed a committee to formulate a set of rules which would obtain such results, and in 1885 the report of this committee was accepted. This code of rules was revised in 1899, and since then have been universally adopted for all boiler trials or tests.

These rules provide for the method of conducting all boiler trials, from the very simplest to the most elaborate.

Purpose of Boiler Trials.—While there are several purposes for which boiler trials may be conducted, the most usual and important are for determining—

(1) The **standard horse power** of a boiler according to the rating of the American Society of Mechanical Engineers.

(2) The **efficiency** of the boiler.

In addition to these two principal purposes, boiler trials are also conducted for the purposes of determining—

(3) The steam making **value of a fuel** as measured by pounds of water evaporated per pounds of fuel.

(4) The coal and steam **consumption** in pounds per indicated **engine horse power** per hour.

STATE.	Kind of Coal.	Per Cent of Ash.	In Heat, Units per Pound.	In Pounds of Water Evaporated.	Percentage of Incombustible Matter.	Heat Units Available for Steam-making.	Horse Power for 1 pound of Coal.	Hyd. Per Cent.
Pennsylvania,	Anthracite,	3.49	14,199	14.70	0	14,500	9.074	19.01
Pennsylvania,	Anthracite,	6.13	13,535	14.01	1	14,355	5.647	14.86
Pennsylvania,	Anthracite,	2.90	14,221	14.72	2	14,210	5.590	14.60
Pennsylvania,	Cannel,	15.02	13,143	13.60	3	14,065	5.533	14.44
Pennsylvania,	Conelssville,	6.50	13,368	13.84	4	13,920	5.436	14.40
Pennsylvania,	Semi-bituminous,	10.77	13,155	13.82	5	13,775	5.418	14.25
Pennsylvania,	Stone's Gas,	5.00	14,021	14.51	6	13,630	5.361	14.10
Pennsylvania,	Youghiogheny,	5.60	14,265	14.76	7	13,485	5.305	13.94
Pennsylvania,	Brown,	9.50	12,324	12.75	8	13,340	5.243	13.80
Kentucky,	Caking,	2.75	14,391	14.89	9	13,195	5.190	13.65
Kentucky,	Cannel,	2.00	15,198	16.76	10	13,050	5.133	13.51
Kentucky,	Cannel,	14.80	13,360	13.84	11	12,905	5.706	13.35
Kentucky,	Lignite,	7.00	9,326	9.65	12	12,760	5.019	13.20
Illinois,	Bureau Co.,	5.20	13,025	13.48	13	12,615	4.962	13.05
Illinois,	Mercer Co.,	5.60	13,123	13.68	14	12,470	4.905	12.90
Illinois,	Montauk,	5.50	12,659	13.10	15	12,325	4.848	12.75
Indiana,	Block,	2.50	13,588	14.38	16	12,180	4.791	12.60
Indiana,	Caking,	5.66	14,146	14.64	17	12,035	4.743	12.45
Indiana,	Cannel,	6.00	13,097	13.56	18	11,890	4.637	12.30
Maryland,	Cumberland,	13.98	12,226	12.65	19	11,745	4.659	12.18
Arkansas,	Lignite,	5.00	9,215	9.94	20	11,600	4.563	12.00
Colorado,	Lignite,	9.25	13,562	14.04	21	11,455	4.545	11.85
Colorado,	Lignite,	4.50	13,866	14.35	22	11,311	4.449	11.70
Texas,	Lignite,	4.50	12,962	13.41	23	11,165	4.392	11.55
Washington,	Lignite,	3.40	11,551	11.96	24	10,920	4.295	11.30

Comparative Value of Fuels.

Table No. 12.

Equivalent Evaporation.—As different boilers generate steam at different pressures, different temperature of the feed water and different degrees of dryness of the steam, it becomes necessary to reduce all these qualities to a **common basis** before the standard boiler horse power can be determined. To do this it is necessary to reduce the **evaporation** to a basis common to all, called the **equivalent evaporation from and at 212 degrees Fahrenheit**. The necessity of this can be seen as boilers do not evaporate all the water pumped into them into **dry** saturated steam, and hence the **actual** evaporation varies greatly with the different character and construction of boilers. In order to ascertain the actual evaporation, it is therefore necessary that the feed water be multiplied by some number or factor representing the amount of **dry steam** contained in every pound of feed water evaporated. Such numbers, or factors, are called **factors of evaporation**, and by their use the actual evaporation of the boiler is readily reduced to the equivalent evaporation from and at 212 degrees Fahrenheit.

In Table No. 13 is given factors of evaporation for the stated gauge pressures.

Factors of Evaporation.—Therefore, to find the equivalent evaporation of any boiler, multiply the actual evaporation by the factor of evaporation. These factors of evaporation can be found in most all engineering works similar to the adjoining table of **Factors of Evaporation**, only differing in the extent to which they are carried out.

Example.—5000 pounds of water per hour is fed to a boiler, the water being at 50 degrees temperature and the steam gauge pressure of the boiler being 100 pounds. How much water will this boiler evaporate per hour from and at 212 degrees?

Temp. re of
Feet Water
Depth

STEAM PRESSURE BY GAUGE.

	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	
32	1.214	1.216	1.220	1.224	1.227	1.230	1.233	1.236	1.239	1.242	1.245	1.248	1.251	1.254	1.257	1.260	1.263	1.266	1.269	1.272	1.275	1.278	1.281	1.284	1.287	1.290	1.293
40	1.266	1.269	1.272	1.275	1.278	1.281	1.284	1.287	1.290	1.293	1.296	1.299	1.302	1.305	1.308	1.311	1.314	1.317	1.320	1.323	1.326	1.329	1.332	1.335	1.338	1.341	1.344
50	1.395	1.397	1.401	1.404	1.407	1.410	1.413	1.416	1.419	1.422	1.425	1.428	1.431	1.434	1.437	1.440	1.443	1.446	1.449	1.452	1.455	1.458	1.461	1.464	1.467	1.470	1.473
60	1.485	1.488	1.491	1.494	1.497	1.500	1.503	1.506	1.509	1.512	1.515	1.518	1.521	1.524	1.527	1.530	1.533	1.536	1.539	1.542	1.545	1.548	1.551	1.554	1.557	1.560	1.563
70	1.575	1.578	1.581	1.584	1.587	1.590	1.593	1.596	1.599	1.602	1.605	1.608	1.611	1.614	1.617	1.620	1.623	1.626	1.629	1.632	1.635	1.638	1.641	1.644	1.647	1.650	1.653
80	1.664	1.667	1.670	1.673	1.676	1.679	1.682	1.685	1.688	1.691	1.694	1.697	1.700	1.703	1.706	1.709	1.712	1.715	1.718	1.721	1.724	1.727	1.730	1.733	1.736	1.739	1.742
90	1.761	1.764	1.767	1.770	1.773	1.776	1.779	1.782	1.785	1.788	1.791	1.794	1.797	1.800	1.803	1.806	1.809	1.812	1.815	1.818	1.821	1.824	1.827	1.830	1.833	1.836	1.839
100	1.864	1.867	1.870	1.873	1.876	1.879	1.882	1.885	1.888	1.891	1.894	1.897	1.900	1.903	1.906	1.909	1.912	1.915	1.918	1.921	1.924	1.927	1.930	1.933	1.936	1.939	1.942
110	1.974	1.977	1.980	1.983	1.986	1.989	1.992	1.995	1.998	2.001	2.004	2.007	2.010	2.013	2.016	2.019	2.022	2.025	2.028	2.031	2.034	2.037	2.040	2.043	2.046	2.049	2.052
120	2.084	2.087	2.090	2.093	2.096	2.099	2.102	2.105	2.108	2.111	2.114	2.117	2.120	2.123	2.126	2.129	2.132	2.135	2.138	2.141	2.144	2.147	2.150	2.153	2.156	2.159	2.162
130	2.194	2.197	2.200	2.203	2.206	2.209	2.212	2.215	2.218	2.221	2.224	2.227	2.230	2.233	2.236	2.239	2.242	2.245	2.248	2.251	2.254	2.257	2.260	2.263	2.266	2.269	2.272
140	2.304	2.307	2.310	2.313	2.316	2.319	2.322	2.325	2.328	2.331	2.334	2.337	2.340	2.343	2.346	2.349	2.352	2.355	2.358	2.361	2.364	2.367	2.370	2.373	2.376	2.379	2.382
150	2.414	2.417	2.420	2.423	2.426	2.429	2.432	2.435	2.438	2.441	2.444	2.447	2.450	2.453	2.456	2.459	2.462	2.465	2.468	2.471	2.474	2.477	2.480	2.483	2.486	2.489	2.492
160	2.524	2.527	2.530	2.533	2.536	2.539	2.542	2.545	2.548	2.551	2.554	2.557	2.560	2.563	2.566	2.569	2.572	2.575	2.578	2.581	2.584	2.587	2.590	2.593	2.596	2.599	2.602
170	2.634	2.637	2.640	2.643	2.646	2.649	2.652	2.655	2.658	2.661	2.664	2.667	2.670	2.673	2.676	2.679	2.682	2.685	2.688	2.691	2.694	2.697	2.700	2.703	2.706	2.709	2.712
180	2.724	2.727	2.730	2.733	2.736	2.739	2.742	2.745	2.748	2.751	2.754	2.757	2.760	2.763	2.766	2.769	2.772	2.775	2.778	2.781	2.784	2.787	2.790	2.793	2.796	2.799	2.802
190	2.834	2.837	2.840	2.843	2.846	2.849	2.852	2.855	2.858	2.861	2.864	2.867	2.870	2.873	2.876	2.879	2.882	2.885	2.888	2.891	2.894	2.897	2.900	2.903	2.906	2.909	2.912
200	2.924	2.927	2.930	2.933	2.936	2.939	2.942	2.945	2.948	2.951	2.954	2.957	2.960	2.963	2.966	2.969	2.972	2.975	2.978	2.981	2.984	2.987	2.990	2.993	2.996	2.999	3.002
210	3.034	3.037	3.040	3.043	3.046	3.049	3.052	3.055	3.058	3.061	3.064	3.067	3.070	3.073	3.076	3.079	3.082	3.085	3.088	3.091	3.094	3.097	3.100	3.103	3.106	3.109	3.112

Factors of Evaporation.
Table No. 13.

Solution.—In the Table of Factors of Evaporation opposite the 50 degrees temperature of the feed water and boiler pressure of 100 pounds, we find the factor 1.20. Now multiply the quantity of water actually evaporated, viz.: 5,000 pounds by this factor of 1.20, and the result will be the water evaporated per hour from and at 212 degrees, viz.: 6,000 pounds.

Should a table of factors not be convenient, then the **equivalent evaporation** is determined as follows:

Rule.—Subtract the temperature of the feed water from the total heat of 1 pound of steam at the pressure of evaporation. Add 32 to the remainder and multiply the sum by the actual evaporation in pounds. Divide the product by 966.1.

Example.—A boiler generates 2,000 pounds of dry steam per hour at a gauge pressure of 120 pounds, the feed water temperature being 60 degrees, what is the equivalent evaporation?

Solution.—From the **steam table**, No. 14, we find the total heat corresponding to a gauge pressure of 120 pounds is 1,188.64 B. T. U. Applying above rule we find:

$$\frac{2,000 \times (1.188.6 - 60 + 32)}{966.1} = 2402.7 \text{ pounds.}$$

Boiler Horse Power Test.—The standard boiler horse power is obtained by dividing the equivalent evaporation as has been explained by $34\frac{1}{2}$, which represents the unit of **one standard** boiler horse power, that being the number of pounds of water evaporated per horse power from and at 212 degrees.

It is therefore seen that **before** we can determine the

horse power of a boiler, it is first necessary to ascertain the **equivalent evaporation** of the boiler..

Efficiency Tests.—To find the efficiency of a boiler, divide the number of heat units usefully expended in evaporating the water by the number of heat units supplied by the fuel.

To find the efficiency in per cent multiply the number of heat units by 100.

Example.—A boiler trial shows a useful expenditure of 120,386.451 B. T. U., and a total supply of 190,841.350 B. T. U., what is the efficiency of the boiler plant?

Solution.—

$$\text{Efficiency} = \frac{100 \times 120,386.451}{190,841.350} = 63 \text{ per cent.}$$

Quality of Steam.—By the quality of steam is meant the **amount** or the per cent of the water pumped into a boiler, that is evaporated into **dry steam**. The amount of dry steam furnished by boilers vary greatly. Most all boilers when generating steam rapidly, furnish a certain amount of wet steam, which is water remaining unevaporated in the steam. As this water does no useful work, in fact, is most objectionable, both on the grounds of safety and economy, it should be **deducted** from the amount of evaporation of the boiler, or it would make the boiler show a higher efficiency than it really possessed.

Calorimeter.—The apparatus used for the purpose of determining the amount of moisture contained in steam is called a **calorimeter**, the simplest form of which is the **Barrel Calorimeter**. Its operation is very simple, consisting of first weighing a barrel holding about 400

Gauge Pressure in lbs. per Square Inch.	Temperature in Degrees F.	Total Heat in Heat Units from Water at 32° F.	Heat Units in Liquid from 32° F.	Heat of Vaporization in Heat Units.	Density or Weight of 1 Cu. ft. in lbs.	Volume of 1 lb. in Cubic Feet.	Weight of 1 Cubic ft. of Water.	Factor of Equivalent Evaporation from and at 212° F.
0	212.00	1146.8	180.8	965.8	0.03760	26.60	59.76 (Formula) 59.64 (Observed)	1.0000
10	239.36	1154.9	208.4	946.5	0.06128	16.32	59.04	1.0086
20	258.68	1160.8	227.9	932.9	0.08439	11.85	58.50	1.0147
30	273.87	1165.5	243.2	922.3	0.1070	9.347	58.07	1.0196
40	286.54	1169.3	255.9	913.4	0.1292	7.736	57.69	1.0235
50	297.46	1172.6	266.9	905.7	0.1512	6.612	57.32	1.0269
55	303.42	1174.2	271.9	902.3	0.1621	6.169	57.22	1.0286
60	307.10	1175.6	276.6	899.0	0.1729	5.784	57.08	1.0300
65	311.54	1176.9	281.1	895.8	0.1837	5.443	56.95	1.0314
70	315.77	1178.2	285.6	892.7	0.1945	5.142	56.82	1.0327
75	319.80	1179.5	289.8	889.8	0.2052	4.873	56.69	1.0341
80	323.66	1180.6	293.8	886.9	0.2159	4.633	56.59	1.0352
85	327.36	1181.8	297.7	884.2	0.2265	4.415	56.47	1.0365
90	330.92	1182.8	301.5	881.5	0.2371	4.218	56.36	1.0375
95	334.35	1183.9	305.0	879.0	0.2477	4.037	56.25	1.0386
100	337.66	1184.9	308.5	876.5	0.2583	3.872	56.18	1.0397
105	340.86	1185.9	311.8	874.1	0.2689	3.720	56.07	1.0407
110	343.95	1186.8	315.0	871.8	0.2794	3.580	55.97	1.0417
115	346.94	1187.7	318.2	869.6	0.2898	3.452	55.87	1.0426
120	349.85	1188.6	321.2	867.4	0.3003	3.330	55.77	1.0435
125	352.68	1189.5	324.2	865.3	0.3107	3.219	55.69	1.0444
130	355.43	1190.3	327.0	863.3	0.3212	3.113	55.58	1.0452
135	358.10	1191.1	329.8	861.3	0.3315	3.017	55.52	1.0461
140	360.70	1191.9	332.5	859.4	0.3420	2.924	55.44	1.0469
145	363.25	1192.8	335.2	857.5	0.3524	2.838	55.36	1.0478
150	365.73	1193.5	337.8	855.7	0.3629	2.756	55.29	1.0486
155	368.62	1194.3	340.3	853.9	0.3731	2.681	55.22	1.0494
160	370.51	1195.0	342.8	852.1	0.3835	2.608	55.15	1.0500
165	372.43	1195.7	345.2	850.4	0.3939	2.539	55.07	1.0508
170	375.09	1196.3	347.6	848.7	0.4043	2.474	54.99	1.0514
175	377.31	1197.0	349.9	847.1	0.4147	2.412	54.93	1.0522
180	379.48	1197.7	352.2	845.4	0.4251	2.353	54.86	1.0529
185	381.60	1198.3	354.4	843.9	0.4353	2.297	54.79	1.0535
190	383.70	1199.0	356.6	842.3	0.4455	2.244	54.73	1.0542
195	385.75	1199.6	358.8	840.9	0.4559	2.193	54.66	1.0549
200	387.76	1200.2	360.9	839.2	0.4663	2.145	54.60	1.0555
225	397.86	1203.1	370.9	832.2	0.5179	1.930	54.27	1.0585
250	406.07	1205.8	380.1	825.7	0.5699	1.755	54.03	1.0613
275	414.22	1208.3	388.5	819.3	0.621	1.609	53.77	1.0639
300	421.83	1210.6	396.5	814.1	0.674	1.488	53.54	1.0666

Table of the Properties of Saturated Steam.

Table No. 14.

pounds of water on a platform scale, the temperature of the water being registered by a thermometer inserted in the side of the barrel.

The steam from the boiler to be tested is then discharged into this barrel, through a hose or pipe until the temperature of the water in the barrel reaches about 140 degrees. The steam is then turned off and the barrel and its contents again weighed. The **difference** between the weights, is the weight of the steam discharged into the water.

If **dry steam** is discharged into the water, it should raise the temperature of the water in the barrel a certain known amount. If the temperature does not raise that much, it then must be due to the steam not being dry, but containing moisture.

From the steam table the temperature of the steam can be found, from which can be determined the amount of moisture in same, which gives the quality of the steam.

Analysis of Coal.—The calorific value of fuels can only be determined by a careful **chemical analysis**, which requires a skilled chemist. Such an analysis should show the moisture, the volatile matter, the carbon and ash in same.

Moisture.—This is found by first weighing a small sample of the coal or fuel in a porcelain or platinum crucible, and then heating same in a drying oven to a temperature of about 225 degrees Fahrenheit. Then weigh the sample again, and the **loss** of weight represents the moisture.

Volatile Matter.—This is determined by weighing out a small portion of the undried pulverized sample into a platinum crucible and **covering tightly**. Heat it for a few minutes over a Bunsen burner, keeping up a bright

Temperature Fahr.	Heat Units per lb.	Weight, lbs. per cubic foot.	Temperature Fahr.	Heat Units per lb.	Weight, lbs. per cubic foot.	Temperature Fahr.	Heat Units per lb.	Weight, lbs. per cubic foot.	Temperature Fahr.	Heat Units per lb.	Weight, lbs. per cubic foot.
32°	0.00	62.42	110°	78.00	61.89	145°	213.26	61.28	179°	247.54	60.37
35	3.02	62.42	112	80.00	61.86	146	214.27	61.26	180	248.54	60.35
40	8.06	62.42	113	81.01	61.84	147	215.28	61.24	181	249.55	60.33
45	13.08	62.42	114	82.02	61.82	148	216.29	61.22	182	250.56	60.30
50	18.10	62.41	115	83.02	61.82	149	217.30	61.20	183	251.57	60.28
55	20.11	62.40	116	84.03	61.80	150	218.30	61.18	184	252.58	60.26
54	22.11	62.40	117	85.04	61.78	151	219.31	61.16	185	253.58	60.24
56	24.11	62.39	118	86.05	61.77	152	220.32	61.14	186	254.59	60.21
58	26.12	62.38	119	87.06	61.75	153	221.33	61.12	187	255.60	60.19
60	28.12	62.37	120	88.06	61.74	154	222.34	61.10	188	256.61	60.17
62	30.12	62.36	121	89.07	61.72	155	223.35	61.08	189	257.62	60.15
64	32.12	62.35	122	90.08	61.70	156	224.36	61.06	190	258.63	60.13
66	34.12	62.34	123	91.09	61.68	157	225.37	61.04	191	259.63	60.10
68	36.12	62.33	124	92.10	61.67	158	226.38	61.02	192	260.63	60.07
70	38.11	62.32	125	93.10	61.65	159	227.38	60.98	193	261.64	60.05
72	40.11	62.31	126	94.11	61.63	160	228.38	60.94	194	262.65	60.02
74	42.11	62.30	127	95.12	61.61	161	229.39	60.90	195	263.66	60.00
76	44.11	62.29	128	96.13	61.60	162	230.40	60.88	196	264.66	60.00
78	46.10	62.28	129	97.14	61.58	163	231.41	60.84	197	265.67	60.00
80	48.09	62.27	130	98.14	61.56	164	232.42	60.80	198	266.68	60.00
82	50.08	62.26	131	99.15	61.54	165	233.43	60.77	199	267.69	60.00
84	52.07	62.25	132	100.16	61.52	166	234.43	60.73	200	268.70	60.00
86	54.06	62.24	133	101.17	61.51	167	235.44	60.69	201	269.71	60.00
88	56.05	62.23	134	102.18	61.49	168	236.45	60.65	202	270.72	60.00
90	58.04	62.22	135	103.18	61.47	169	237.46	60.61	203	271.73	60.00
92	60.03	62.21	136	104.19	61.45	170	238.47	60.57	204	272.74	59.97
94	62.02	62.20	137	105.20	61.43	171	239.47	60.53	205	273.75	59.95
96	64.01	62.19	138	106.21	61.41	172	240.48	60.49	206	274.76	59.92
98	66.01	62.18	139	107.22	61.39	173	241.49	60.45	207	275.77	59.89
100	68.01	62.17	140	108.23	61.37	174	242.50	60.41	208	276.78	59.86
102	70.00	62.16	141	109.24	61.35	175	243.51	60.37	209	277.79	59.84
104	72.00	61.97	142	110.24	61.34	176	244.52	60.34	210	278.80	59.82
106	74.00	61.95	143	111.25	61.32	177	245.53	60.31	211	279.81	59.79
108	76.00	61.92	144	112.26	61.30	178	246.54	60.29	212	280.82	59.76

B. T. U. in a Pound of Water at Different Temperatures.

Table No. 15.

red heat and then heat without cooling over a blast furnace for the same length of time at a white heat. Allow the sample to cool and weigh it. The loss in weight represents the loss of the hydrocarbons and the moisture, these being known as the **volatile matter**.

Fixed Carbon.—Place what is left of the sample, after having determined the volatile matter as above explained, into a crucible and weigh it. Then heat it over a Bunsen burner, holding the crucible, which is open to the air, in such a position that it will be exposed to the direct heat or flame of the burner. In this way all the carbon will be burned off, leaving only the **ash**. Now weigh the crucible and the **difference** in the weights is the amount of **fixed carbon** which was originally in the sample. The crucible should be heated in this way several times and weighed each time in order to be certain that all the carbon has been burned out of the sample.

Ash.—To ascertain the amount of ash, either subtract the weight of the crucible from the combined weight of it and the ash, or weigh the ash directly on the scales.

Comparative Value of Fuels.—Table No. 12 shows the value for steam making of American coals from and at 212 degrees Fahrenheit:

Petroleum.—Crude oil, fuel oil, or any distillate:

Per cent of ash, .0.

Heat units per pound, 20.746.

Pounds of water evaporation, 21.47.

Per cent incombustible matter, 25.

Heat units available for steam-making, 10.920.

Horse power per pound, 4.238.

Evaporation per pound from and at 212 degrees Fahrenheit, 11.25.

Comparative Cost.—To estimate the cost of oil as compared with other fuels, the following table shows the heat units in each of the most common fuels, from which the cost can be readily figured, taking as a basis the number of heat units in one gallon of oil as 151,000 B. T. U.

	Heat Units per 1,000 cubic feet.
Natural Gas	1,000,000
Air Gas (Gas Machine), 20 candle power.	815,500
Public Illuminating Gas, average.....	650,000
Water Gas (from Bituminous Coal)....	377,000
Water and Producer Gas, mixed.....	175,000
Producer Gas	150,000

With oil at 4 cents a gallon, the cost of equivalent heat would be as follows:

	Per 1,000 cubic feet.
Natural Gas	at .264
Air Gas, 20 candle power.....	at .216
Public Illuminating Gas, average.....	at .172
Water Gas (from Bituminous Coal).....	at .099
Water. and Producer Gas, mixed.....	at .046
Producer Gas	at .039

Illuminating Gas.—

	Per 1,000 cubic feet.
With oil at 7 cents, would equal gas.....	at .301
With oil at 8 cents, would equal gas.....	at .340
With oil at 9 cents, would equal gas.....	at .387
With oil at 10 cents, would equal gas.....	at .430
With oil at 11 cents, would equal gas.....	at .473
With oil at 12 cents, would equal gas.....	at .516

Natural Gas.—

Per 1,000 cubic feet.

With oil at 5 cents, would equal gas.....at	.330
With oil at 6 cents, would equal gas.....at	.397
With oil at 7 cents, would equal gas.....at	.463
With oil at 8 cents, would equal gas.....at	.529

Wood.—Perfectly dry wood contains about 50 per cent carbon, and for steam raising purposes about 2 1/3 pounds of dry wood are equal to 1 pound average quality of soft coal. Wood is usually classified as hard or soft.

Hard woods include oak, maple, hickory, birch, walnut and beech.

Soft woods consist of pine, fir, spruce, elm, chestnut, poplar and willow.

It has been found that hard wood gives less heat per pound than soft wood.

Calorific Values of Woods.—The relative calorific value of different woods as compared with coal is as follows, viz.:

Cord of Wood.—	Value in lbs. of Coal.
Hickory, shell bark.....	1910
Oak, chestnut	1690
Oak, white	1670
Ash, white	1440
Dogwood	1560
Oak, black	1390
Oak, red	1390
Beech, white	1380
Maple, hard (sugar).....	1230
Maple, soft	1140
Cedar, red	1080
Magnolia	1160
Pine, yellow	1060
Sycamore	1020

Butternut	1090
Pine, New Jersey.....	916
Pine, pitch	812
Pine, white	800
Poplar, Lombardy	761
Chestnut	1000
Poplar, yellow	1080

Values in British Thermal Units Per Pound.—The value of different kinds of wood in B. T. U. per pound, on a basis of 1 pound of coal equals $2 \frac{1}{3}$ pounds of dry wood, is as follows:

Name.	B. T. U.
Oak	8316
Ash	8480
Elm	8510
Beech	8591
Birch	8586
Fir	9063
Pine	9153
Poplar	7834
Willow	7926

Refuse.—This includes refuse, garbage and all character of municipal waste. Below is given the results of official tests made in several English cities of the fuel value of refuse, the evaporation being taken from and at 212 degrees Fahrenheit:

Accrington, 1.39 pounds.
 Beckenhowe, 1.512 pounds.
 Blackburn, 1.297 pounds.
 Bolton, 0.8 pounds.
 Bradford, 0.882 pounds.
 Bury, 1.58 pounds.
 Colme, 1.00 pounds.

RULES FOR CONDUCTING BOILER TRIALS.

Adopted by the American Society of Mechanical Engineers.

Code of 1898. (Abridged.)

I. Determine at the outset the specific object of the proposed trial, whether it be to ascertain the capacity of the boiler, its efficiency as a steam generator, its efficiency and its defects under usual working conditions, the economy of some particular kind of fuel, or the effect of changes of design, proportion, or operation; and prepare for the trial accordingly.

II. Examine the boiler, both outside and inside; ascertain the dimensions of grates, heating surfaces, and all important parts; and make a full record, describing the same, and illustrating special features by sketches. The area of heating surface is to be computed from the outside diameter of water tubes and the inside diameter of fire tubes.

III. Notice the general condition of the boiler and its equipment, and record such facts in relation thereto as bear upon the objects in view.

IV. Determine the character of the coal to be used. For tests of the efficiency or capacity of the boiler for comparison with other boilers, the coal should, if possible, be of some kind which is commercially regarded as a standard.

For New England and that portion of the country east of the Allegheny mountains, good anthracite egg coal, containing not over 10 per cent of ash, and semi-bituminous Clearfield (Pa.), Cumberland (Md.), and Pocahontas (Va.) coals are thus regarded. West of the Allegheny mountains, Pocahontas (Va.) and New River (W. Va.) semi-bituminous, and Youghiogeny or Pitts-

burg bituminous coals are recognized as standards. There is no special grade of coal mined in the Western States which is widely recognized as of superior quality or considered as a standard coal for boiler testing. Big Muddy lump, an Illinois coal mined in Jackson County, Ill., is suggested as being of sufficiently high grade to answer the requirements in districts where it is more conveniently obtainable than the other coals mentioned above.

V. Establish the correctness of all apparatus used in the test for weighing and measuring. These are:

1. Scales for weighing coal, ashes, and water.
2. Tanks, or water meters for measuring water. Water meters, as a rule, should only be used as a check on other measurements. For accurate work, the water should be weighed or measured in a tank.
3. Thermometers and pyrometers for taking temperatures of air, steam, feed water, waste gases, etc.
4. Pressure gauges, draught gauges, etc.

The kind and location of the various pieces of testing apparatus must be left to the judgment of the person conducting the test; always keeping in mind the main object, i. e., to obtain authentic data.

VI. See that the boiler is thoroughly heated to its usual working temperature before the trial. If the boiler is new and of a form provided with a brick setting, it should be in regular use at least a week before the trial, so as to dry and heat the walls. If it has been laid off and becomes cold, it should be worked before the trial until the walls are well heated.

VII. The boiler and connections should be proved to be free from leaks before beginning a test, and all water connections, including blow and extra feed pipes, should be disconnected, stopped with blank flanges, or

bled through special openings beyond the valves, except the particular pipe through which water is to be fed to the boiler during the trial. During the test the blow-off and feed pipes should remain exposed to view.

If an injector is used, it should receive steam directly through a felted pipe from the boiler being tested.

If the water is metered after it passes the injector, its temperature should be taken at the point where it leaves the injector. If the quantity is determined before it goes to the injector the temperature should be determined on the suction side of the injector, and if no change of temperature occurs other than that due to the injector, the temperature thus determined is properly that of the feed water. When the temperature changes between the injector and the boiler, as by the use of a heater or by radiation, the temperature at which the water enters and leaves the injector and that at which it enters the boiler should all be taken. In that case the weight to be used is that of the water leaving the injector, computed from the heat units if not directly measured, and the temperature, that of the water entering the boiler.

Let w = weight of water entering the injector.

x = weight of steam entering the injector.

h_1 = heat units per pound of water entering injector.

h_2 = heat units per pound of steam entering injector.

h_3 = heat units per pound of water leaving injector.

Then $w + x$ = weight of water leaving injector.

$$x = w \frac{h_3 - h_1}{h_2 - h_3}$$

See that the steam main is so arranged that water of condensation cannot run back into the boiler.

VIII. Duration of the Test.—For tests made to ascertain either the maximum economy or the maximum capacity of a boiler, irrespective of the particular class of service for which it is regularly used, the duration should be at least ten hours of continuous running. If the rate of combustion exceeds 25 pounds of coal per square foot of grate surface per hour, it may be stopped when a total of 250 pounds of coal has been burned per square foot of grate.

In cases where the service requires continuous running for the whole 24 hours of the day, with shifts of firemen a number of times during that period, it is well to continue the test for at least 24 hours.

When it is desired to ascertain the performance under the working conditions of practical running, whether the boiler be regularly in use 24 hours a day or only a certain number of hours out of each 24, the fires being banked the balance of the time, the duration should not be less than 24 hours.

IX. Starting and Stopping a Test.—The conditions of the boiler and furnace in all respects should be, as nearly as possible, the same at the end as at the beginning of the test. The steam pressure should be the same; the water level the same; the fire upon the grates should be the same in quantity and condition; and the walls, flues, etc., should be of the same temperature. Two methods of obtaining the desired equality of conditions of the fire may be used, viz.: those which were called in the Code of 1885, "the standard method" and "the alternate method," the latter being employed where it is inconvenient to make use of the standard method.

X. Standard Method of Starting and Stopping a Test.—Steam being raised to the working pressure, re-

move rapidly all the fire from the grate, close the damper, clean the ash-pit, and as quickly as possible start a new fire with weighed wood and coal, noting the time and the water level while the water is in a quiescent state, just before lighting the fire.

Note.—The gauge glass should not be blown out within an hour before the water level is taken at the beginning and end of a test, otherwise an error in the reading of the water level may be caused by a change in the temperature and density of the water in the pipe leading from the bottom of the glass into the boiler.

At the end of the test remove the whole fire, which has been burned low, clean the grates and ash-pit, and note the water level when the water is in a quiescent state, and record the time of hauling the fire. The water level should be as nearly as possible the same as at the beginning of the test. If it is not the same, a correction should be made by computation and not by operating the pump after the test is completed.

XI. Alternate Method.—The boiler being thoroughly heated by a preliminary run, the fires are to be burned low and well cleaned. Note the amount of coal left on the grate as nearly as it can be estimated; note the pressure of steam and the water level, and note this time as the time of starting the test. Fresh coal which has been weighed should now be fired. The ash pits should be thoroughly cleaned at once after starting. Before the end of the test the fires should be burned low, just as before the start, and the fires cleaned in such a manner as to leave the bed of coal of the same depth, and in the same condition, on the grates as at the start. The water level and steam pressures should previously be brought as nearly as possible to the same point as at the start, and the time of ending of the test should

be noted just before fresh coal is fired. If the water level is not the same as at the start, a correction should be made by computation, and not by operating the pump after the test is completed.

XII. Uniformity of Conditions.—In all trials made to ascertain maximum economy or capacity, the conditions should be maintained uniformly constant. Arrangements should be made to dispose of the steam so that the rate of evaporation may be kept the same from beginning to end.

Uniformity of conditions should prevail as to the pressure of steam, the height of water, the rate of evaporation, the thickness of fire, the times of firing and quantity of coal fired at one time, and as to the intervals between the times of cleaning the fires.

XIII. Keeping of Records.—Take note of every event connected with the progress of the trial, however unimportant it may appear. Record the time of every occurrence and the time of taking every weight and every observation.

The coal should be weighed and delivered to the fireman in equal proportions, each sufficient for not more than one hour's run, and a fresh portion should not be delivered until the previous one has all been fired. The time required to consume each portion should be noted, the time being recorded at the instant of firing the last of each portion. It is desirable that at the same time the amount of water fed into the boiler should be accurately noted and recorded, including the height of the water in the boiler, and the average pressure of steam and temperature of feed during the time. In addition to these records of the coal and the feed water, half hourly observations should be made of the temperature of the feed water, of the flue gases, of the external air

in the boiler room, of the temperature of the furnace when a furnace pyrometer is used, also of the pressure of steam, and of the reading of the instruments for determining the moisture in the steam. A log should be kept on properly prepared blanks containing columns for record of the various observations.

XIV. Quality of Steam.—The percentage of moisture in steam should be determined by the use of either a throttling or a separating steam calorimeter. The sampling nozzle should be placed in the vertical steam pipe rising from the boiler. It should be made of $\frac{1}{2}$ -inch pipe, and should extend across the diameter of the steam pipe to within half an inch of the opposite side, being closed at the end and perforated with not less than twenty $\frac{1}{2}$ -inch holes equally distributed along and around its cylindrical surface, but none of these holes should be nearer than $\frac{1}{2}$ -inch to the inner side of the steam pipe. The calorimeter and the pipe leading to it should be well covered with felting. Whenever the indications of the throttling or separating calorimeter show that the percentage of moisture is irregular, or occasionally in excess of 3 per cent, the results should be checked by a steam separator placed in the steam pipe as close to the boiler as convenient, with a calorimeter in the steam pipe just beyond the outlet from the separator. The drip from the separator should be caught and weighed, and the percentage of moisture computed therefrom added to that shown by the calorimeter.

Superheating should be determined by means of a thermometer placed in a mercury-well inserted in the steam pipe. The degree of superheating should be taken as the difference between the reading of the thermometer for superheated steam and the readings of the

same thermometer of saturated steam at the same pressure as determined by a special experiment, and not by reference to steam tables.

XV. Sampling the Coal and Determining Its Moisture.—As each barrow load or fresh portion of coal is taken from the coal pile, a representative shovelful is selected from it and placed in a barrel or box in a cool place and kept until the end of the trial. The samples are then mixed and broken into pieces not exceeding 1 inch in diameter, and reduced by the processes of repeated quartering and crushing until a final sample weighing about 5 pounds is obtained, and the size of the larger piece is such that they will pass through a sieve with $\frac{1}{4}$ -inch meshes. From this sample two one-quart, air-tight glass preserving jars, or other air-tight vessels which will prevent the escape of moisture from the sample, are to be promptly filled, and these samples are to be kept for subsequent determinations of moisture and of heating value and for chemical analyses. During the process of quartering, when the sample has been reduced to about 100 pounds, a quarter to a half of it may be taken for an approximate determination of moisture. This may be made by placing it in a shallow iron pan, not over 3 inches deep, carefully weighing it, and setting the pan in the hottest place that can be found on the brickwork of the boiler setting or flues, keeping it there for at least 12 hours, and then weighing it. The determination of moisture thus made is believed to be approximately accurate for anthracite and semi-bituminous coals, and also for Pittsburg or Youghiogheny coal; but it cannot be relied upon for coals mined west of Pittsburg, or for other coals containing inherent moisture. For these latter coals it is important that a more accurate method be adopted. The method recom-

mended by the committee for all accurate tests, whatever the character of the coal, is described as follows:

Take one of the samples contained in the glass jars, and subject it to a thorough air-drying, by spreading it in a thin layer and exposing it for several hours to the atmosphere of a warm room, weighing it before and after, thereby determining the quantity of surface moisture it contains. Then crush the whole of it by running it through an ordinary coffee mill adjusted so as to produce somewhat coarse grains (less than $1/16$ inch), thoroughly mix the crushed sample, select from it a portion of from 10 to 50 grams, weigh it in a balance which will easily show a variation as small as 1 part in 1,000, and dry it in an air or sand bath at a temperature between 240 and 280 degrees Fahrenheit for 1 hour. Weigh it and record the loss, then heat and weigh it again repeatedly, at intervals of an hour or less, until the minimum weight has been reached and the weight begins to increase by oxidation of a portion of the coal. The difference between the original and the minimum weight is taken as the moisture in the air-dried coal. This moisture test should preferably be made on duplicate samples, and the results should agree within 0.3 to 0.4 of 1 per cent, the mean of the two determinations being taken as the correct result. The sum of the percentage of moisture thus found and the percentage of surface moisture previously determined is the total moisture.

XVI. Treatment of Ashes and Refuse.—The ashes and refuse are to be weighed in a dry state. If it is found desirable to show the principal characteristics of the ash, a sample should be subjected to a proximate analysis and the actual amount of incombustible material determined. For elaborate trials a complete analysis of the ash and refuse should be made.

XVII. Calorific Tests and Analysis of Coal.—The quantity of the fuel should be determined either by heat test or by analysis, or by both.

The rational method of determining the total heat or combustion is to burn the sample of coal in an atmosphere of oxygen gas, the coal to be sampled as directed in Article XV of this code.

The chemical analysis of the coal should be made only by an expert chemist. The total heat of combustion computed from the results of the ultimate analysis may be obtained by the use of Dulong's formula.

It is desirable that a proximate analysis should be made, thereby determining the relative proportions of volatile matter and fixed carbon. These proportions furnish an indication of the leading characteristics of the fuel, and serve to fix the class to which it belongs. As an additional indication of the characteristics of the fuel, the specific gravity should be determined.

XVIII. Analysis of Flue Gases.—The analysis of the flue gases is an especially valuable method of determining the relative value of different methods of firing, or of different kinds of furnaces. In making these analyses great care should be taken to procure average samples—since the composition is apt to vary at different points of the flue. The composition is also apt to vary from minute to minute, and for this reason the drawing of gas should last a considerable period of time. Where complete determinations are desired, the analyses should be intrusted to an expert chemist. For approximate determinations the Orsat or the Hempel apparatus may be used by the engineer.

For the continuous indication of the amount of carbonic acid (CO_2) present in the flue gases, an instru-

ment may be employed which shows the weight of the sample of gas passing through it.

XIX. Smoke Observations.—It is desirable to have a uniform system of determining and recording the quantity of smoke produced where bituminous coal is used. The system commonly employed is to express the degree of smokiness by means of percentages dependent upon the judgment of the observer. The committee does not place much value upon a percentage method, because it depends so largely upon the personal element, but if this method is used, it is desirable that, so far as possible, a definition be given in explicit terms as to the basis and method employed in arriving at the percentage. The actual measurement of a sample of soot and smoke by some form of meter is to be preferred.

XX. Miscellaneous.—In tests for purposes of scientific research, in which the determination of all the variable entering into the test is desired, certain observations should be made which are in general unnecessary for ordinary tests. These are the measurement of the air supply, the determination of its contained moisture, the determination of the amount of heat lost by radiation, of the amount of infiltration of air through the setting, and (by condensation of all the steam made by the boiler) of the total heat imparted to the water.

As these determinations are rarely undertaken, it is not deemed advisable to give directions for making them.

XXI. Calculations of Efficiency.—Two methods of

defining and calculating the efficiency of a boiler are recommended. They are:

1. Efficiency of the boiler

$$\frac{\text{Heat absorbed per lb. combustible}}{\text{Calorific value of 1 lb. combustible}}$$
2. Efficiency of the boiler and grate

$$\frac{\text{Heat absorbed per lb. coal}}{\text{Calorific value of 1 lb. coal}}$$

The first of these is sometimes called the efficiency based on combustible, and the second efficiency based on coal. The first is recommended as a standard of comparison for all tests, and this is the one which is understood to be referred to when the word "efficiency" alone is used without qualification. The second, however, should be included in a report of a test, together with the first, whenever the object of the test is to determine the efficiency of the boiler and furnace together with the grate (or mechanical stoker), or to compare different furnaces, grates, fuels, or methods of firing.

The heat absorbed per pound of combustible (or per pound of coal) is to be calculated by multiplying the equivalent evaporation from and at 212 degrees per pound combustible (or coal) by 965.7.

XXII. The Heat Balance.—An approximate "heat balance," or statement of the distribution of the heating value of the coal among the several items of heat utilized and heat lost may be included in the report of a test when analyses of the fuel and of the chimney gases have been made. The methods of computing the heat balance and the form in which it should be reported, are given in Steam Boiler Efficiency.

XXIII. Report of the Trial.—The data and results

should be reported in the manner given in either one of the two following tables, omitting lines where the tests have not been made as elaborate as provided for in such tables. Additional lines may be added for data relating to the specific object of the test. The extra lines should be classified under the headings provided in the tables, and numbered as per preceding line, with sub-letters a, b, etc. The short form of report is recommended for commercial tests, and as a convenient form of abridging the longer form for publication when saving of space is desirable. For elaborate trials, it is recommended that the full log of the trial be shown graphically, by means of a chart.

TABLE OF DATA AND RESULTS OF EVAPORATIVE TEST,

Arranged in Accordance With the Short Form Advised
by the Boiler Test Committee of the American
Society of Mechanical Engineers.

Made by.....on.....boiler, at.....to
determine

Grate surface	sq. ft.
Water-heating surface	sq. ft.
Superheating surface	sq. ft.
Kind of fuel.....	
Kind of furnace.....	

Total Quantities.

1. Date of trial.....	
2. Duration of trial.....	hours.
3. Weight of coal as fired.....	lbs.
4. Percentage of moisture in coal.....	per cent.
5. Total weight of dry coal consumed...	lbs.
6. Total ash and refuse.....	lbs.
7. Percentage of ash and refuse in dry coal	per cent.

- | | | |
|----|---|------|
| 8. | Total weight of water fed to the boiler | lbs. |
| 9. | Water actually evaporated, corrected for moisture or superheat in steam.. | lbs. |

Hourly Quantities.

- | | | |
|-----|--|------|
| 10. | Dry coal consumed per hour..... | lbs. |
| 11. | Dry coal per hour per square foot of grate surface | lbs. |
| 12. | Water fed per hour..... | lbs. |
| 13. | Equivalent water evaporated per hour from and at 212 degrees corrected for quality of steam..... | lbs. |
| 14. | Equivalent water evaporated per square foot of water-heating surface per hour | lbs. |

Average Pressures, Temperatures, Etc.

- | | | |
|-----|--|------------------|
| 15. | Average boiler pressure..... | lbs. per sq. in. |
| 16. | Average temperature of feed water... | deg. |
| 17. | Average temperature of escaping gases | deg. |
| 18. | Average force of draft between damper and boiler | ins. of water. |
| 19. | Percentage of moisture in steam, or number of degrees of superheating. | |

Horse Power.

- | | | |
|-----|--|-----------|
| 20. | Horse power developed (Item 13 \div 34 $\frac{1}{2}$) | H. P. |
| 21. | Builders' rated horse power..... | H. P. |
| 22. | Percentage of builders' rated horse power | per cent. |

Economic Results.

- | | | |
|-----|--|------|
| 23. | Water apparently evaporated per pound of coal under actual conditions. (Item 8 \div Item 3)..... | lbs. |
| 24. | Equivalent water actually evaporated from and at 212 degrees per pound | |

- of coal as fired. (Item 13 \div (Item 5 \div 2)) lbs.
25. Equivalent evaporation from and at 212 degrees per pound of dry coal. (Item 13 \div Item 10) lbs.
26. Equivalent evaporation from and at 212 degrees per pound of combustible. [Item 13 \div [(Item 5.— Item 6) \div Item 2] lbs.
(If Items 23, 24 and 25 are not corrected for quality of steam, the fact should be stated.)

Efficiency.

27. Heating value of the coal per pound.. B. T. U.
28. Efficiency of boiler (based on combustible)
29. Efficiency of boiler, including grate (based on coal).....

Cost of Evaporation.

30. Cost of coal per ton delivered in boiler room \$
31. Cost of coal required for evaporation of 1,000 pounds of water from and at 212 degrees..... \$

AVERAGE DIMENSIONS OF WATER TUBE BOILERS.

From "The Engineer."

Boiler. Horse- power	No. Tubes in Width	No. Tubes in Height	Length in Feet	Diam. of Drum, Inches	Length of Drum, Feet	Average Weight in Tons	Length of Selling, Feet	Width of Selling, Feet	Height of Selling, Feet	No. of Common Brick	No. of Fire Brick	Diam. of Valve, In.	Heating Surface in Sq. Ft.	Area of Grate, Sq. Ft.
10	3	4	6	24	10	3	9	4	8½	2200	590	2	119	5.21
12	3	4	8	24	12	3½	11	4	8½	2620	740	2	150	6.25
15	3	5	8	24	12	3½	11	4	9	2760	790	2	181	7.28
20	3	5	10	24	15	4½	13	4	9	3170	980	2	219	8.33
25	4	5	10	30	15	5	13	5	9½	3350	1000	2½	293	10.67
30	4	5	12	30	17	5½	15	5	9½	3760	1170	2½	343	10.67
35	4	6	12	30	17	6	16	5½	11	5970	1510	3	401	12.00
40	4	6	14	30	19	6½	19	5½	11	7460	1680	3	460	13.33
45	4	7	14	30	19	7	19	5½	11	8630	1410	3½	526	13.33
50	4	8	14	30	19	7½	19	5½	12	8920	1540	3½	593	13.33
55	5	8	14	36	19	8½	19	6	12½	9180	1600	3½	735	16.25
65	5	8	16	36	21	10	21	7	12	9890	1650	3½	870	19.17
75	6	7	16	36	21	11	21	7	12½	10500	1738	4	983	19.17
85	6	8	16	36	21	11½	21	7	13	10900	1950	4	1098	23.00
95	6	9	18	36	24	12	23	7	13½	12570	1970	5	1218	23.00
105	6	9	18	36	24	12½	23	7½	13	13400	2000	5	1265	26.50
110	7	8	18	36	24	12½	23	7½	13½	12750	2010	5	1411	26.50
120	7	9	18	36	24	12½	23	7½	14	12800	2160	5	1426	26.50
125	7	9	18	42	24	14	23	8	14	13200	2060	5	1619	30.00
140	8	9	18	42	24	14	23	8	14	13160	2020	4	1741	36.67
150	12	7	16	36	21	13½	21	10	12½	12960	2060	5	1827	33.50
160	9	9	18	48	24	16½	23	8	14½	13180	2160	4	1968	34.67
175	12	8	16	36	21	13½	21	10	13	13300	2200	4	2197	44.00
190	12	9	16	36	21	20½	21	10	13½	13500	2230	5	2437	44.00
210	12	9	18	36	24	20½	23	10	13½	13800	2310	5	2531	51.00
220	14	8	18	36	24	21½	23	11½	13	14000	2350	5	2823	51.00
240	14	9	18	36	24	23½	23	11½	13½	14000	3000	5	2853	51.00
250	14	9	18	43	24	24½	23	11½	14	14000	3000	5	2853	51.00

Table No. 16.

ANALYSES OF WATER

ANALYSES OF WATER	lime and Magnesia Carbonates	lime and Magnesia Sulphates	Sodium Chloride (Salt)	Iron Oxide, etc.	Volatile and Organic Matter	Inorganic Matter	Organic and Volatile Matter	Total Solids in Grains
Albany, N. Y., City Supply	..	..	..	..	..	8.47	2.31	10.78
Boston, City Supply, Cochituate	..	..	..	..	..	2.40	0.71	3.11
Buffalo, N. Y., Lake Erie	5.66	3.32	0.58	..	0.18	9.66	1.18	10.74
Chicago, Lake Michigan	..	..	..	..	..	..	..	15.30
Girard, O. (River)	6.18	3.72	2.93	0.71	1.76	..	..	22.90
Madison, Wis. (River)	6.23	4.67	1.76	20.14	6.50	..	..	39.30
Milwaukee, O., Water Works	9.93	5.52	1.17	1.98	4.30	..	..	22.90
New York City (Croton River)	..	..	..	..	..	6.20	0.67	6.87
Peoria, Ill.	5.47	6.43	5.85	2.05	4.90	..	..	24.90
Pittsburgh, Allegheny River	0.37	3.78	0.58	0.37	1.50	..	..	6.60
Pittsburgh, Monongahela River	1.06	5.12	0.64	0.78	3.20	..	..	10.80
Philadelphia, Schuylkill River	..	..	1.42	0.07	0.67	2.30	1.20	3.50
Rockford, Ill.	25.98	..	0.66	0.78	..	..	..	28.14
Indianapolis, Ind. (Deep Well)	16.12	11.19	5.10	1.78	..	..	..	17.84
"	26.22	..	..	..	..	12.13	1.23	44.29
Syracuse, N. Y., Reservoir	..	..	..	..	..	5.50	0.96	13.25
Utica, N. Y.	..	..	..	..	..	10.00	1.50	6.46
Younstown, O., Mahoning River	..	..	..	..	..	..	..	11.50
Appleton, Wis., Fox River	7.04	1.46	trace	trace	1.70	..	..	10.20
Blue Island, Ill., Calumet River	5.55	3.35	0.88	2.62	3.70	..	..	16.10
Bay City, Mich., Bay	8.47	10.36	20.48	1.15	8.74	..	..	49.24
Bay City, Mich., River	4.84	33.66	126.78	3.00	10.92	..	..	179.20
Columbus, O.	20.76	11.74	7.02	0.58	6.50	..	..	46.60
Cincinnati, O., River	3.88	0.78	1.79	..	trace	..	..	6.73
Decatur, Ill., City Supply	15.66	1.32	2.34	trace	2.88	..	..	22.20
Fort Wayne, Ind.	8.78	6.22	3.51	1.59	10.98	..	..	31.08
Findlay, O.	18.22	6.39	1.17	0.31	6.27	..	..	32.96
Flint, Mich., City Supply	11.06	6.32	0.88	0.04	3.30	..	..	21.60
Fond du Lac, Wis., City Supply	9.44	9.52	6.54	trace	4.20	..	..	23.70
Kansas City, Mo.	8.10	4.20	1.76	1.04	5.60	..	..	20.70
Kenosha, Wis., City Supply	14.04	12.02	0.88	trace	9.26	..	..	40.60
Lima, O.	5.28	5.82	9.95	0.55	7.50	..	..	28.60
Muncie, Ind., M. P. Co.	15.92	0.72	0.59	0.17	2.70	..	..	20.10
Madison, Wis., U. of W.	9.20	trace	trace	trace	2.80	..	..	12.00
Peoria, Ill., City Supply	17.80	3.42	1.76	trace	3.82	..	..	26.90
Springfield, Ill.	12.17	5.03	trace	trace	2.10	..	..	19.30

CHAPTER XIV.

QUESTIONS AND ANSWERS ON PRECEDING CHAPTERS.

Q. What is **sanitary** engineering?

A. It is that branch of engineering which pertains to heating and ventilating.

Q. What is necessary for a thorough knowledge of heating?

A. A knowledge of **boilers**, and the properties of steam and heat.

Q. How may the various **systems** of heating by steam be classed?

A. Into (1) high pressure systems; (2) low pressure systems; (3) vacuum or exhaust systems.

Q. What is meant by these different systems?

A. In the first class are all systems that require for heating a **greater** boiler pressure than 15 pounds per square inch; in the second class are those that operate between 15 pounds pressure and the atmospheric pressure; while in the third class are all systems that work at a **lower** pressure than the atmospheric, that is, require a **partial vacuum** for their successful operation.

Q. How may each of these systems in turn be subdivided?

A. Into (1) the one pipe system; (2) the two-pipe system; (3) the two-pipe system with separate return risers, and (4) overhead main or drop supply system.

Q. How may these subdivisions be further subdivided?

A. Into (1) the gravity return system, and (2) the forced return system.

Q. What is the operation of the one-pipe system?

A. In this system the steam from the boiler is carried to the risers through **one** pipe, the condensation flowing back through the **same** pipe.

Q. What is the operation of the **two-pipe** system?

A. This system has two connections for each radiator, one serving as an inlet for the **steam** and the other as an outlet for the **water** of condensation, the steam passing through one pipe and the water flowing back to the boiler through the return pipe.

Q. What is the operation of the exhaust or back pressure system?

A. In this system the steam heating main is connected to the **exhaust pipe** from the engine or pump, and also to a **live** steam pipe from the boiler. This live steam is only used when there is an **insufficiency** of exhaust steam. Should the supply of exhaust steam become **excessive**, the excess will escape by the opening of the back pressure valve and its discharge into the atmosphere.

Q. What is the operation of the vacuum system?

A. In this system the returns are connected to a receiver which collects the air and water in the system. To this receiver is connected a **vacuum pump** which removes all the air and water in the system, and maintains a **vacuum** at any desired degree. When this system is used there is **no** back pressure on the engine.

Q. What are **hot water** heating systems?

A. Hot water systems are very similar to the steam systems, except that **hot water** flows through the pipes and radiators instead of steam.

Q. How is the temperature in a hot water heating system regulated?

A. By varying the temperature of the **water** flowing through the pipes.

Q. What is meant by central station heating?

A. It is the heating of large districts from **one central plant**, instead of from separate plants in each building or dwelling.

Q. How is the heat transmitted from the central station?

A. Through pipes properly insulated, which are usually laid underground.

Q. What is meant by one **boiler horse power**?

A. It is the evaporation of 34.48 pounds of water from and at 212 degrees Fahrenheit, or the evaporation of 30 pounds of water per hour from feed water having a temperature of 100 degrees Fahrenheit into steam at 70 pounds pressure. It is equal to the **absorption** of 33,330 B. T. U. by the water in the boiler.

Q. What is meant by the **efficiency** of a boiler?

A. It is the ratio between the heat units utilized in the production of steam, and the heat units contained in the fuel used.

Q. What is the equivalent evaporation?

A. It is the reduction to a **common basis** of the evaporation of different boilers operating under different conditions.

Q. What are factors of evaporation?

A. They are the numbers or factors representing the amount of dry steam under different pressures contained in every pound of feed water evaporated.

Q. How do you find the equivalent evaporation of any boiler?

A. Multiply the actual evaporation by the factor of evaporation.

Q. What is a calorimeter?

A. It is an apparatus used for the purpose of determining the amount of **moisture** contained in steam.

Q. What are the standard rules for conducting boiler trials?

A. The rules adopted by the American Society of Mechanical Engineers.

The following table, taken from experiments of Mr. Brill, indicates the savings due to various coverings, the cost of the covering and the cost of applying the same, at the time these experiments were made, viz. . 1895.

Kinds of Covering	Savings Due to Coverings				Cost to Apply 60 Feet of Covering	Cost of 60 Feet of Covering	Gross Saving in One Year Due to 60 Feet Covering
	Per Hour per Square Foot Pipe		Per 100 Square Feet per Year				
	B. T. U.	Pounds Steam	Pounds Steam	Dollars			
Magnesia	631.966	.7258	685901	110.82	\$1.92	\$31.95	\$150.14
Rock wool	666.637	.7666	670666	116.90	2.02	27.60	156.38
Mineral wool	658.988	.7568	662367	115.55	2.34	21.00	156.55
Fire felt	599.730	.6988	608889	105.17	2.10	29.70	142.48
Manville sectional	641.295	.7365	645174	112.45	3.21	29.35	162.85
Manville sectional and hair felt	678.777	.7798	682980	119.08	5.96	34.60	161.26
Manville wool cement	642.601	.7390	646488	112.68	17.06	25.50	152.66
Champion mineral wool	650.277	.7493	654197	114.03	2.85	16.02	154.49
Hair felt	621.588	.7139	626376	109.00	3.90	10.50	147.87
Riley cement	477.022	.5479	479980	88.66	50.00	8.71	118.84
Fossil meal	497.274	.5711	500284	87.30	12.76	21.45	118.14

Pipe Covering.
Table No. 18.

CHAPTER XV.

THE STEAM ENGINE.

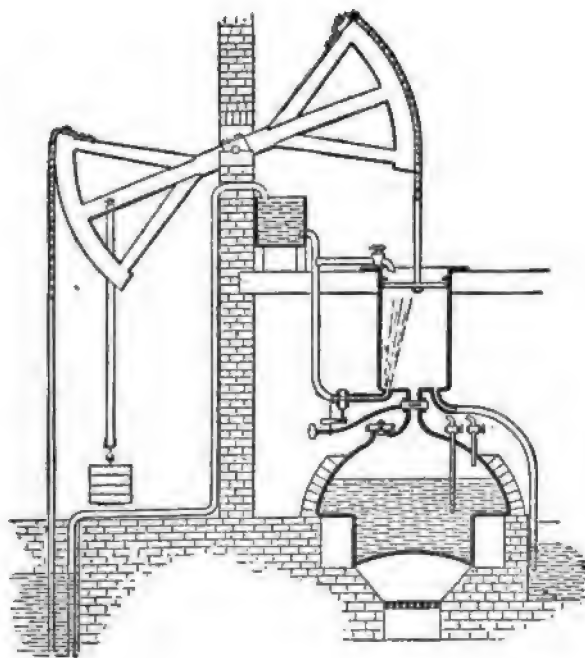
Definition.—The **Steam Engine** is an apparatus for converting heat into mechanical power.

The Savery Engine.—The first practical engine was constructed by Thomas Savery in the year 1693, and was used to pump water out of a mine, as were all the first constructed engines. It consisted simply of two oval vessels placed side by side and in communication with a boiler. The lower parts of the vessels were connected by tubes fitted with suitable valves; steam from the boiler was admitted to one of the vessels, and then condensed by cooling the surface of the vessel with water. In this way a **vacuum** was formed inside the vessel, which upon opening the valve, drew up the water from the mine until the vessel was full. The valve was then closed and steam again admitted, so that upon opening the second valve the water was forced out through the discharge pipe. The two vessels were worked **alternately**, so that while one was being filled, the other was open to the boiler and being emptied.

Defect.—The waste of steam in this apparatus was enormous, the consumption of coal being about **twenty times** as great as required by a modern steam engine to do the same amount of work.

The Newcomen Engine.—In 1705 Newcomen greatly improved upon the Savery engine by reducing the amount of steam necessary to be condensed in operating the Savery engine, by making use of a **piston** which worked in a **cylinder**.

In the Newcomen engine shown in Fig. 134 there was a horizontal lever or beam pivoted at the center, and carrying at one end a heavy rod which connected with



Sectional View of the Newcomen Engine.
Fig. 134.

the pump in the mine below. A piston was hung from the other end of this lever, which piston worked up and down in a cylinder open at the top. Steam at atmospheric pressure was admitted from the boiler to this cylinder, and as the pressure was the same on **both** sides of the piston, the falling of the heavy pump rod **raised** the piston.

A jet of water was then introduced into the cylinder to condense the steam and form a vacuum. This left the piston with the pressure of the atmosphere, which is about 15 lbs. to the square inch, on one side of it, and but little pressure on the other, which difference in pressure forced the piston **down**, and in this way **raised** the pump rod. Steam was then again admitted into the cylinder and condensed, forcing the piston down again, and the pump in this way operated.

Cylinders.—The cylinders were usually made of **wood** and the workmanship so poor that a **tight** joint could not be made between the piston and the walls of the cylinder. This permitted the steam to escape from around the piston. To prevent this as much as possible, a jet of water was made to play on the top of the piston thus making a **water seal**, through which the steam could not escape.

One of the greatest troubles with all the first engines constructed was that they required some one to open and close the cocks to admit the steam and water, boys being usually employed for this work. In order to get time to play, one of them, rigged a catch at the end of a cord which was attached to the overhead beam, and in this way the first **automatic** engine was constructed. While the Newcomen engine was a **great** improvement on all previous efforts, it was also most **wasteful** and clumsy. Later, the cylinders were made of **iron**



**Newcomen Pumping Engine, Bardsley, Near Ashton-Under-Lyne.
Out of Use 1830.**

**From Mr. Henry Davey's paper before the Institution of
Mechanical Engineers.**

instead of wood, but they were cast rough, and the workmanship far from perfect.

The James Watt Engine.—In the year 1764 James Watt, who was an instrument maker in Glasgow, Scotland, devised the present type of steam engine, and while the **workmanship** of the steam engine has been much improved since that day, no great improvement has been made upon his **ideas and suggestions**, with the one exception of **compound expansion**. All other improvements have been merely carrying out his ideas, which lack of good tools alone prevented him from executing.

Steam Engine Efficiency.—Watt found that to obtain the best results from a steam engine that it was necessary

“First, that the temperature of the cylinder should always be the same as that of the steam which entered it; and, secondly, that when the steam was condensed it should be cooled to as low a temperature as possible.”

Separate Condenser.—Instead of condensing the steam in the cylinder itself, he used a **separate** vessel or **condenser** into which he injected the water to condense the steam. In this way he kept the cylinder almost as hot as the entering steam. He made the piston **tight** by using greater care in its construction, so that it was not necessary to keep it under a water seal, which seal greatly cooled the piston and the cylinder walls.

Closed Cylinder.—All his predecessors had left **one** end of the cylinder open, which permitted the steam to be used only on **one** side of the piston, but **Watt** closed **both** ends of the cylinder, thus not only preventing the air from cooling the piston, but permitted the steam to act on **both** sides of the piston, making the engine double acting.

In order to keep the cylinder as hot as the entering

steam, he **jacketed** the cylinder; but what was far more important, he used the steam **expansively**, that is, the steam was shut off when the piston had made only **a part** of the stroke, permitting the **expansion** of the steam to complete the stroke, and thus adding greatly to the **economy** of the engine in the saving of steam, which would be otherwise wasted.

Classes of Engines.—Engines are classified according to the **work** for which they are built, as, (1) stationary, portable, etc.; (2) from the **arrangement** of the cylinders, as, simple, compound, triple expansion, etc.; (3) according to the character of the **valves** to control the distribution of the steam, as plain slide valve, automatic cut off, Corliss, etc.; (4) according to the **motion** of the piston, as reciprocating and rotary.

Subdivisions.—The principal subdivisions of these types of engines are (1) condensing engines, (2) non-condensing engines, (3) single acting engines, (4) double acting engines.

Definition of Types.—A stationary steam engine is an engine designed to remain in the **same place** where installed, doing its work without changing its location.

Engines that operate factories, office buildings, electric light plants or any character of **stationary** steam plants, belong to this class.

A **portable steam engine** is an engine designed to be **moved** from place to place, or one that does its work while in transit.

Such engines as marine and locomotive engines are portable engines, they being designed to propel steamships or trains of cars from place to place. Also, hoisting engines, steam hammers, steam drills, and all pumping, blowing and fire engines belong to this class of en-

gines, as they are capable of being moved with ease from place to place.

Simple Engine.—This is an engine in which the steam is used expansively in only one cylinder. Should the steam be used in **more** than one cylinder before being exhausted or discharged, the engine is then said to be a **multiple expansion engine**.

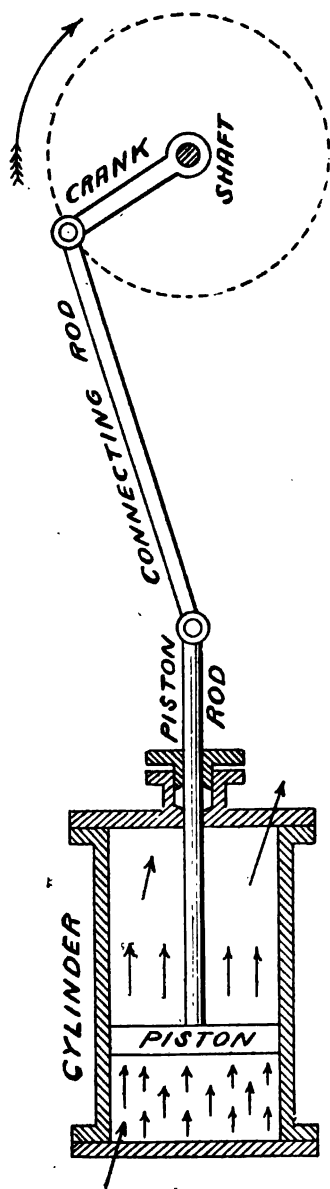
Compound Engine.—This is an engine which has **two** cylinders, the steam being expanded **twice** before its final discharge.

Triple Expansion Engine is one which has **three** cylinders, that is the steam is expanded **three** times before its discharge.

Reciprocating Steam Engine.—In this type of engine the work is done by the reciprocating motion of the piston, that is, its motion back and forth in the cylinder. This reciprocating motion of the piston must be changed into a continuous **rotary** motion before the power of the engine can be used. The form of mechanism used for this purpose is practically the same for all types of reciprocating engines. This reciprocating mechanism is shown in the diagram Fig. 135.

Rotary Engine.—In this type of engine the piston instead of **returning** to its starting point, continues turning in one direction, the piston and crank being connected to the shaft and rotating in the same chamber. In this type of engine the steam is not used expansively as is done in the reciprocating engine.

Non-Condensing Engine.—In this type of engine the steam after having been expanded in the cylinder down to the atmospheric pressure, or near that pressure as



The Reciprocating Mechanism of an Engine.
Fig. 135.

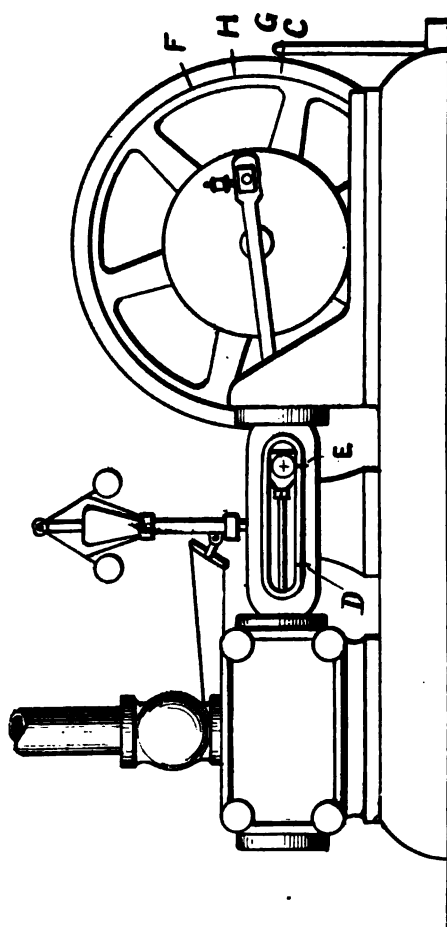
possible, is discharged into the atmosphere, or into a heating system.

Condensing Engines.—In this type of engine the steam is discharged into a **condenser** where it is brought in contact with some cooling substances, usually cold water, by which it is condensed, and a partial **vacuum** is produced behind the piston. The object of condensing the steam behind the piston, is to remove as much as possible the **back pressure** on the piston, and to thus **increase the mean effective pressure** on it throughout its stroke. The back pressure **decreases** the power of the engine it being just so much additional work for the engine to do, and therefore it adds to the **economy** of the engine to remove it, this gain in economy amounting to as much as 20 to 25 per cent, depending on the size and type of the engine. All engines would be made condensing were it not for the increased first cost of the engine, together with the additional labor and attention necessary. Also, at times it is more economical to use the exhaust steam for heating purposes. The cost of the necessary water for condensing purposes is also in many places greater than would be the saving in fuel, as it requires about 25 times as much water for condensing, as for the steam which is used by the engine.

Single Acting Engine.—This is an engine in which the steam acts only on one side of the piston.

Double Acting Engine.—This is the form of engine now generally used, the steam acting on **both** sides of the piston.

Parts of the Steam Engine.—In Fig. 147. is shown the reciprocating mechanism of an ordinary steam engine, while in Fig. 137 is shown in elevation the usual type of a **simple steam engine**, together with the principal parts.



To Place Engine on Center.
Fig. 136.

Reciprocating Parts.—These are all the parts which move back and forth, either in a horizontal or a vertical direction. They are viz.: (1) the piston; (2) the piston rod; (3) the cross head and (4) the connecting rod. The connecting rod is attached to the crosshead, the cross-head to the piston rod, the piston rod to the piston, and on the piston the **pressure** of the steam is exerted to perform the work to be done by moving it back and forth in the cylinder.

The Cylinder is that part of the engine in which the piston moves. It is made of **cast iron** and accurately bored, for should there be any unevenness it would permit the steam to pass through between the piston and cylinder walls, or, if **too tight**, it will cause the piston to stick, or work with too much **friction**.

The **cylinder heads** cover the ends of the cylinder, being securely bolted thereon, thus making the cylinder steam tight. In the **crank end** of the cylinder head, that is the end nearer the crank, there is left an **opening** through which the piston rod passes. This opening is made steam tight by a **stuffing box** which surrounds the piston rod.

The **piston rod** is made of steel and connects the cross-head and the piston, to which it is rigidly fixed.

• The **cross-head** serves to **join** the piston rod and connecting rod. It is guided by the cross-head **guides**.

The **connecting rod** is a steel forging from 3 to 8 times the length of the crank, depending on the type of the engine. One of its ends is joined to the cross-head by the **wrist-pin**, while the other end is fastened to the crank by the **crank pin**, and this end revolves with the crank in a circle while the other end slides back and forth with the cross-head, and in this way is changed the **reciprocating** motion of the piston, into the **circular** motion of the crank and fly wheel.

The **crank pin** forms the connection between the crank and the connecting rod.

The **crank**, which is equal in length to **one-half** the stroke of the piston or engine, converts the reciprocating motion of the connecting rod into a circular motion as above explained. The crank may be simply an **arm**, or a complete **disc**, keyed to one end of the shaft as shown in the above Figs. 148 and 137.

The **shaft** transmits the rotary motion from the crank to the fly wheel. The **steam chest** receives the steam directly from the **boiler**, before it passes through the steam ports to the cylinder. The **eccentric** is a disc, keyed to the shaft so that its center and the center of the shaft do not coincide. It is a species of a crank, its peculiarity being that its crank pin is increased to such a size that it **exceeds** the diameter of the shaft.

The distance between the center of the crank pin and the center of the shaft, is called the **radius of eccentricity**. The radius therefore is the distance between the center of the disc and the center of the shaft.

Eccentric.—In Fig. 141 is shown a diagram of an eccentric, the parts of which are as follows: (1) shaft center; (2) eccentric center; (3) radius of eccentric, (4) eccentric strap; (5) set bolts; (6) eccentric rod; (7) eccentric rod foot.

The distance 8 is called the **throw** of the eccentric, and is twice the radius, or the difference between the heavy and light sides of the eccentric. The eccentric is therefore equivalent to a **crank** whose length is equal to the radius of the eccentric.

The Engine Base.—This must be massive enough to absorb the vibrations of the moving parts, thus reducing the wear on all the parts of the engine as much as possible. It also serves as a top plate to the masonry,

permitting the engine to be set and aligned with accuracy.

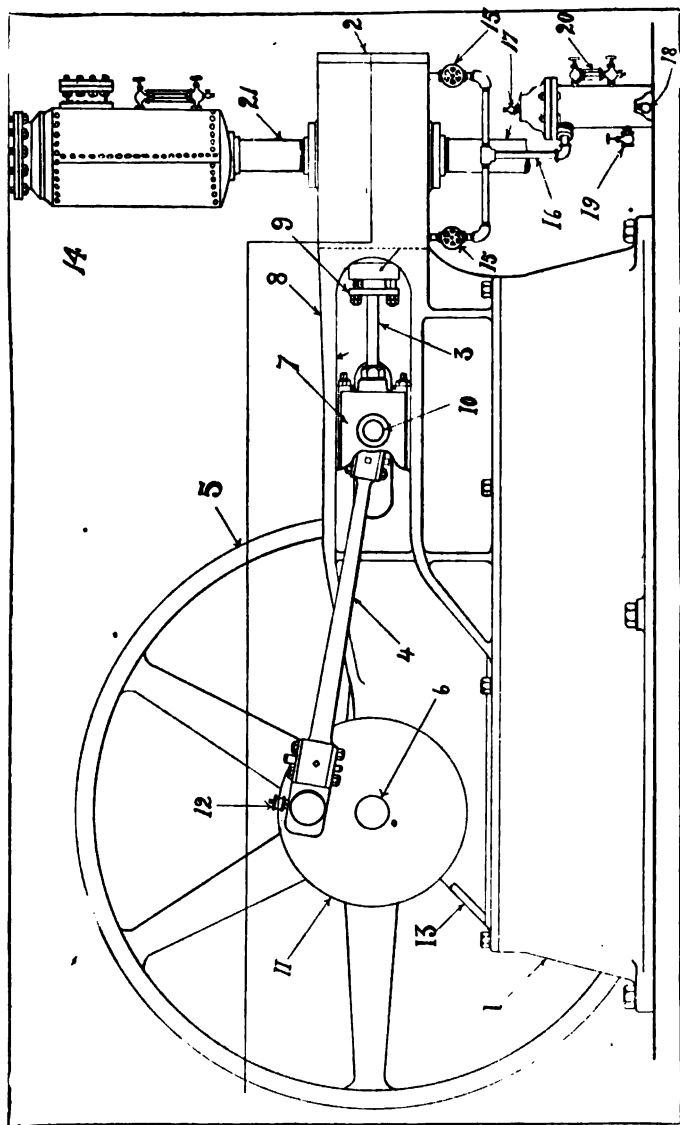
The **Tangee** or **Porter-Allen** type of engine frame has only **one** main bearing for the crank shaft, and is most commonly used for high speed engines.

In the **Girder** type of engine frame, the crank end and cylinder end are supported on **separate** foundations, the middle part between the supports carrying the cross-head slides.

All the principal parts of an ordinary steam engine are shown in Fig. 137 and 148, and they must be **thoroughly** understood and remembered in order to understand the **operation** of the steam engine.

In Fig. 137 is shown the side elevation of a high speed horizontal engine, with steam separator and trap, in which the principal parts are as follows, the numbers corresponding to those shown in this illustration, viz.:

1. Engine frame.
2. Cylinder head.
3. Piston rod.
4. Connecting rod.
5. Belt or fly wheel.
6. Shaft.
7. Crosshead.
8. Engine frame.
9. Stuffing box gland.
10. Wrist pin.
11. Crank wheel.
12. Crank pin oil cup.
13. Engine frame.
14. Steam separator.
15. Cylinder cocks.
16. Drain pipe.



The Parts of a Simple Engine, Showing Separator and Trap.
Fig. 137.

17. Vent cock of trap.
18. Discharge of trap.
19. Blow off valve of trap.
20. Water glass for trap.
21. Steam inlet pipe to engine.

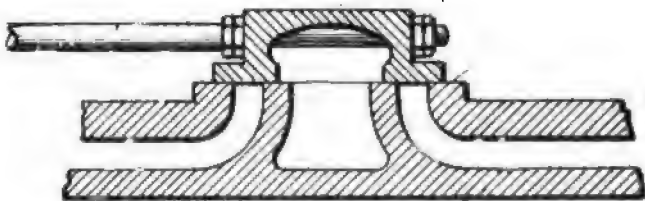
In Fig. 145 is shown a sectional view of the piston, with parts of the connecting rod and piston rod, numbered as follows:

2. Section of piston.
3. Recesses for piston rings.
4. Section of piston.
5. Strap for crosshead brasses.
6. Wrist pin brasses.
7. Connecting rod.
8. Strap bolts crank end.
9. Key for adjusting crank pin brasses.
10. Crank pin brasses.
11. Strap for crank pin brasses.

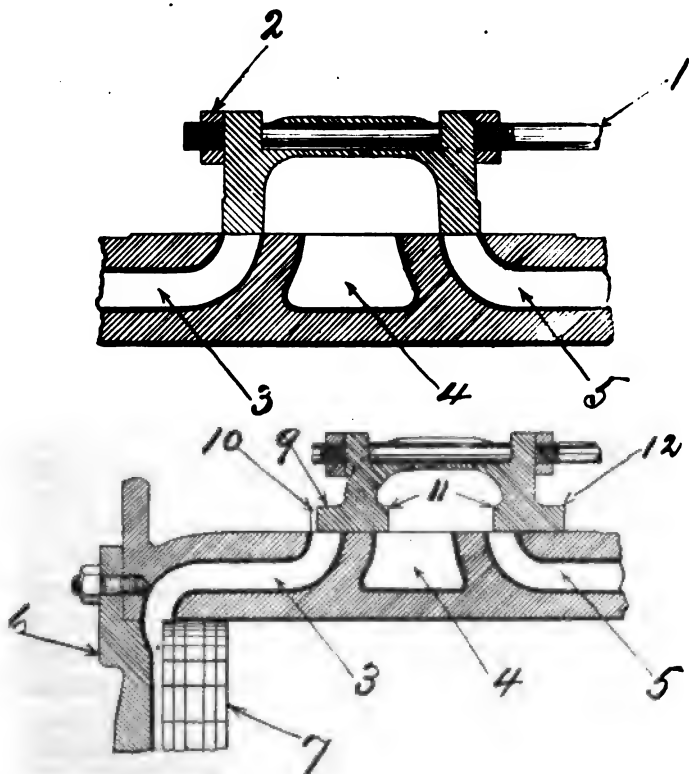
Valves and Valve Gears.—In most engines the steam distributing valves receive their motion from one or more eccentrics and to have a perfect understanding of any character of engine, the **first essential** is to have a thorough understanding of the **valves** and **valve gear** by which is meant the distributing valves, the eccentric, the eccentric strap, the eccentric rod, the rocker and the valve stem. Engines are usually constructed either with a single valve, or with four valves.

Single Valve Engine.—In this type of engine, a **single** valve controls the admission and distribution of the steam for both ends of the cylinder, as in the common slide valve engine.

Four Valve Engine.—Such an engine has **separate** valves for the admission of the steam to the cylinder, and



Sectional View of Ordinary Slide Valve.
Fig. 138.



Section of Ordinary Slide Valve, With and Without Lap and Lead.
Fig. 139.

for its discharge or exhaust, as a Corliss engine. These valves are placed at each end of the cylinder.

Common Slide Valve Engine.—The simplest valve gear is that of the slide valve type, which is usually operated with one eccentric which is fastened to the shaft of the engine.

The "D" Slide Valve and Steam Distribution.—In Fig. 139 is shown the ordinary slide valve, the upper diagram showing it **without** lap or lead, and the lower diagram with **both** lap and lead. Owing to its resemblance to the letter "D," this valve is usually called the "D" Slide Valve.

The valve itself is box-shaped, and slides back and forth on a flat seat which forms a part of the cylinder. This flat seat has long rectangular openings which communicate with curved passages, called **ports**, which lead to each end of the cylinder. As the valve moves to the **right**, it uncovers the **left** port, permitting the steam to enter the **left** end of the cylinder. The steam cannot enter the other end of the cylinder for that port, or opening, is closed, being covered by the valve. The larger **central** port, called the **exhaust** port, is always closed to the **live** steam. By live steam is meant **fresh** steam, as it possesses all its energy, it not having done any work.

The steam pressure therefore forces the piston towards the **right** end of the cylinder. When it reaches that end, the valve uncovers both the right port on one side of the piston, which admits the live steam, and the **exhaust** port on the opposite side of the piston, through which is discharged or exhausted the now useless steam. the piston being again forced to the left end of cylinder. In order to open the exhaust port, so that the pressure on the opposite side of the piston will be at once re-

moved, the valve at its middle is made hollow, and by bringing at the same time the hollow part of the valve over the **middle** port and over the end port towards which the piston is moving, these two ports are put in communication with each other, permitting the steam behind the piston to escape, or be exhausted as it is called.

The upper diagram of Fig. 139 shows the valve in its **central** position, in which position steam is neither admitted to the cylinder nor exhausted from it. Numbers 3 and 5 are the steam ports through which steam is **admitted** into the cylinder. 4 is the exhaust port through which the steam **escapes** from the cylinder after it has done its work. This port 4 is in communication with the atmosphere, or a condenser. 1 is the valve rod by which the valve is moved back and forth across the steam ports 3 and 5. This valve rod is connected to the eccentric, from which it derives its motion. 7 is the piston against which the steam acts to rotate the crank or disc which is fastened to the engine shaft.

In the position of the valve shown in the upper diagram of the Fig 139, should the steam be admitted to the steam chest, which is a chamber in which the valve operates, then, as **both** the steam ports 3 and 5 leading to the ends of the cylinder are closed by the valve, no steam can pass into the cylinder and hence no force would be exerted upon the piston, and therefore all parts of the engine would remain stationary.

In the position of the valve shown in the lower diagram of Fig. 139, the engine is on the center, the left port 3 being slightly open and the piston 7 just beginning its **forward** stroke. By forward stroke is meant the moving of the piston from the head end to the crank end of the cylinder, that is, from the left to the right. 6

is the head end cylinder cover from which the piston is just beginning to move.

As the piston moves forward in the stroke, the valve will further uncover the left port 3, thus admitting more steam to act against the piston, and this admission of steam will continue until the valve entirely uncovers this port and again closes it. On the return stroke of the piston, which is from the crank end to the head end, this port 3 opens to permit the steam in the cylinder which will then be behind the piston, to exhaust through the port 4, the live steam then entering through the right port 5.

So we see that on the return stroke the process is reversed, the port 5 being for the admission of the steam, and the port 3 for its exhaust. This motion of the valve distributing the steam alternately first to the left and then to the right, will continue until the steam is finally shut off from the engine by closing the throttle valve, thus bringing the engine to a stop.

It is therefore seen that the piston in the cylinder of an engine is propelled back and forth by the expansive force of the steam which is admitted alternately at either end of the cylinder, and acts first on one side of the piston to drive it forward and then upon the other side to drive it back to the starting point.

As the steam is under great pressure, sometimes as high as 200 pounds to the square inch, the force acting on the piston at any given instant is enormous. In an engine with the cylinder 16 inches in diameter and with 100 pounds average steam pressure acting upon it, this force will amount to as much as 20,100 pounds throughout the **entire** stroke of the piston.

After the steam has forced the piston to the end of the cylinder, the valve opens the exhaust port and allows

the steam to escape, or exhaust. All this must be done by the valve precisely at the right moment.

An engine running at a speed of 300 revolutions per minute, makes 600 strokes per minute, as the piston must travel twice the length of the cylinder during each revolution of the crank. This means 600 admissions and 600 exhausts per minute, or **10 per second**. Not only must the valve move with this **great rapidity**, but also with the **greatest accuracy**, as it must open the port to admit the steam, and then close it at the proper moment, and then allow it to remain closed long enough for the steam to expand should the valve have lap, and then again open it for its discharge.

As the human mind and body are not capable of thinking and acting with such rapidity, the valve must be operated **automatically**, which means **self-acting** from the forces within itself.

Expansion.—In order that the expansive properties of steam may be **fully utilized**, its admission to the cylinder must be cut off **before** the piston arrives at the end of the stroke, thus allowing the remainder of the stroke to be made by the force of the expansion of the steam alone, unaided by the continuance of the boiler pressure. In order to confine the steam within the cylinder after its admission is cut off, the valve must continue to keep the steam port closed so that the steam cannot escape.

Cut Off.—This is the point of a piston's travel at which the steam admission port closes, no further steam being admitted into the cylinder during the stroke.

With the valve shown in the upper diagram of Fig. 139 this could not be done, the steam being admitted the **entire** stroke of the piston, as the steam port could not be closed by the valve until it started on its return stroke.

Outside Lap.—In order to cut off the steam before the piston completes its stroke, the edge of the valve must be made **wider** than the steam port; and the distance that the valve overlaps the outer edge of the port when the valve is in its central position is called **outside lap**.

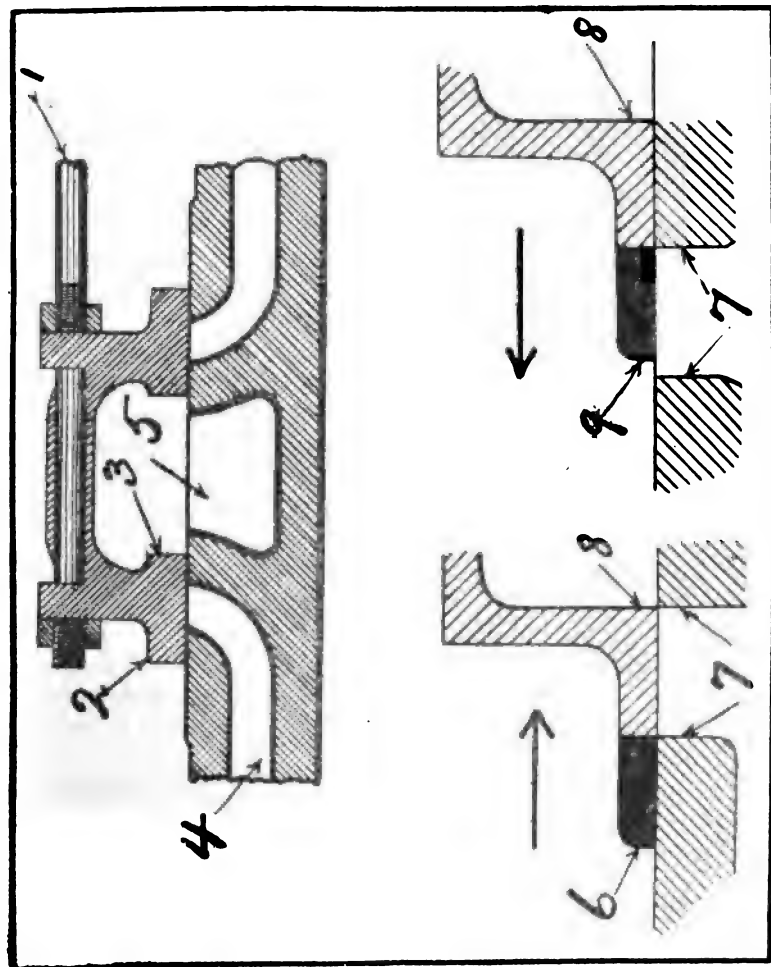
In Fig. 140 the valve is shown in its central position equally covering the steam ports, and the space 2 therefore represents the outside lap on the valve. This outside lap, much magnified, is shown by 6 in the lower diagram of Fig. 140. The black space in this diagram represents the distance that the edge of the valve overlaps the edge of the steam port, and hence is called the outside lap of the valve.

The first valve shown in Fig. 139 did not do this and in order to add this lap, the faces of the valve must be lengthened so as to overlap the steam ports as above described. After the steam is cut off by this extra edge or lap 6, the steam is then confined and expanded in the cylinder until the inside edge 8 of the valve comes even with the inside edge 7 of the steam port, at which instant the exhaust begins.

The object therefore of outside lap on a valve is to utilize as much as possible the **expansive** properties of the steam.

Inside Lap.—In Fig. 140, 3 represents the **inside lap** on the valve, it being the distance that the valve overlaps the **inner** edge of the steam port when the valve is in its central position. The object of putting inside lap on a valve is to close the exhaust port **before** the piston reaches the end of the return stroke, thus holding back some of the exhaust steam, and thereby increasing the pressure at the end of the stroke of the piston.

The effect of this is to make the engine run more



Section of Ordinary Slide Valve, Showing Outside and Inside Lap.

Fig. 140.

smoothly, by bringing the reciprocating parts to rest by the piston striking this **cushion** of steam.

This also saves steam, for it causes the waste room at the end of the cylinder, called the **clearance**, to be filled with exhaust steam, which will therefore not have to be filled with live steam.

Clearance.—By clearance in a cylinder is meant the space allowed for the piston to clear the cylinder heads at the end or beginning of a stroke, that is, the spaces left between the piston and the heads of the cylinder, including the volume of the admission ports.

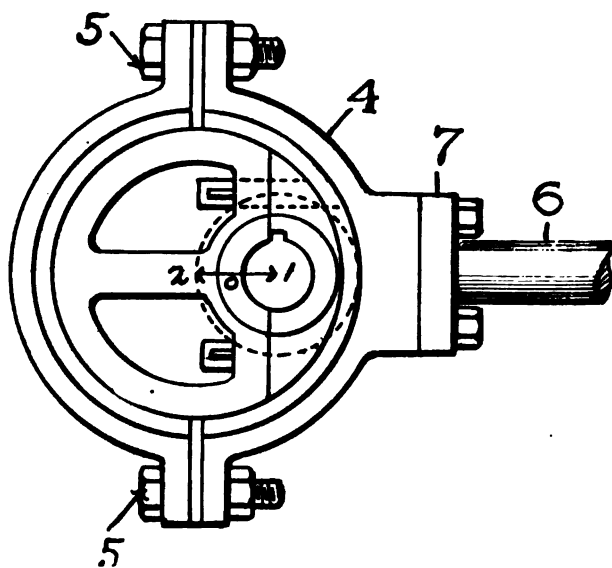
Lead.—This is the amount that the valve leads the crank, for it is the space the steam ports are open when the engine is on its center. In Fig. 139 is shown an engine on one of its centers, and in the figure the space 10 is the **lead** of the valve, it being the amount the steam port is open when the piston is at the beginning of the stroke.

For instance, when the engine is on one of its centers, the valve is opened $\frac{1}{8}$ of an inch, we say that it has $\frac{1}{8}$ of an inch lead.

The **object** of giving a valve lead is not only to form a cushion to take up lost motion, but it also helps to **start** the stroke with full steam pressure, as well as assisting to reverse the stroke.

High speed engines are usually given much **more** lead than the ordinary slow speed engine.

Should the valve have **neither** lap nor lead, then when the piston is at either end of the cylinder, the valve is in **mid position** so that the engine takes steam **full stroke**, that is, the admission port remains open during the entire travel of the piston from one end of the cylinder to the other end. Steam is therefore admitted and exhausted during the whole stroke of the



The Eccentric, Showing Parts.

Fig. 141.

piston, which is most **wasteful** of steam, and for this reason but **few** engines are now built which take steam full stroke.

Principles.—As the above principles apply to all valves of whatever type, size or description, they should be thoroughly understood before proceeding further.

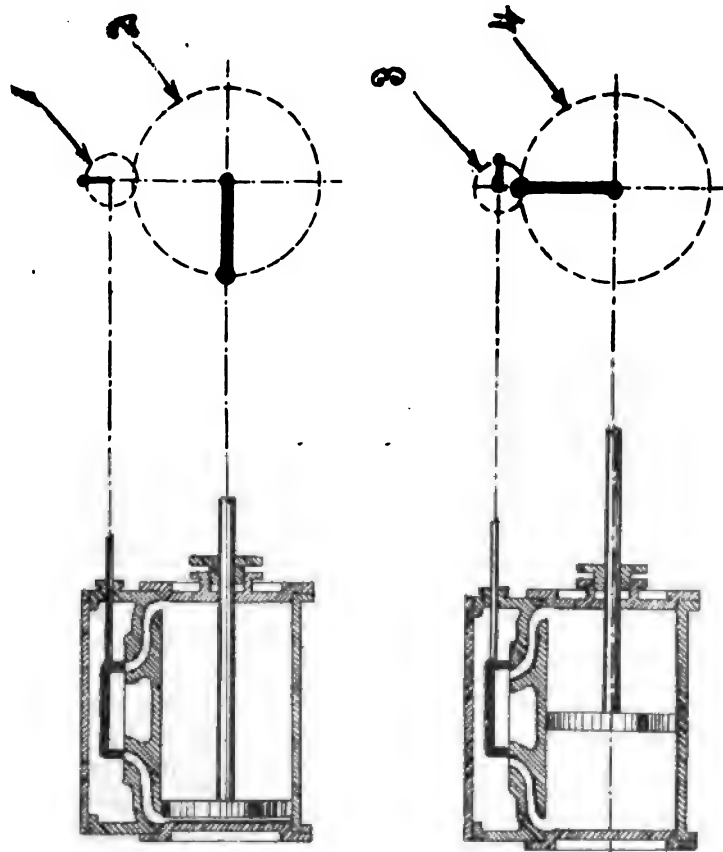
We therefore see that the **power** which operates the steam engine is the **expansion** of the steam. In the same way the gas engine is operated by the **expansion** of a mixture of gas and air burned in the cylinder; and an oil or hot air engine, by the **expansion** of the oil or heated air in the cylinder

Now, this mechanical work is obtained in all the above forms of energy by the expenditure of **heat**.

As steam expands 1669 times its volume under atmospheric pressure, that is, one cubic inch of water will make one cubic foot of steam; the enormous power of the steam engine, which utilizes this priceless property of steam, can be seen. While **all** steam engines are operated by this expansive force of steam, the **full stroke** engines cannot utilize as much of this energy of steam as the automatic cut off engine, which engine fills only a **part** of its cylinder during each stroke with steam, and allows expansion to do the rest.

In the **automatic**, or variable cut off engine, steam is taken at boiler pressure into the cylinder, not for the entire stroke, which would necessitate its being exhausted into the air at the end of the stroke without expansion, but only for a **portion** of the stroke, usually one-half or less, except in some fixed cut off engines which take steam from one-half to three-quarters of the stroke.

Angle of Advance.—In Fig 142 is shown the position of the crank and eccentric when the valve has **neither** lap nor lead. The upper diagram shows the



Position of Crank and Eccentric When Valve Has Neither Lap Nor Lead.
Fig. 142.

valve in its central position, covering both steam ports, and the piston at the end of the stroke. The engine is therefore on center, the crank and the connecting rod being in line.

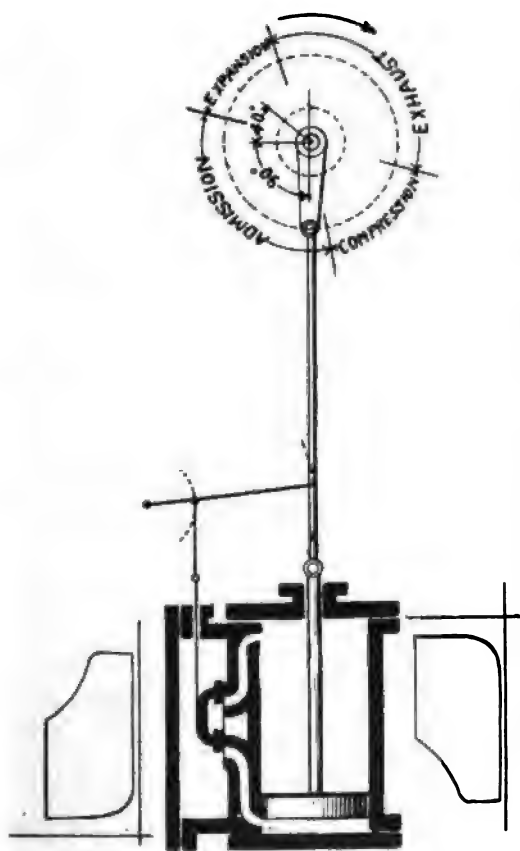
The eccentric 1, which operates the valve, is in a vertical position, and at a right angle, or 90 degrees, to the position of the crank.

Now when the piston moves to the position as shown in the **lower** diagram of Fig. 142, the eccentric has moved the valve until it has uncovered the left steam port, and the eccentric 3 has taken a horizontal position, while the crank 4 is now in a **vertical** position, but the two are still at a right angle to each other, and they remain at this angle of 90 degrees during the entire revolution of the crank.

We therefore see that when the valve has **neither** lap nor lead, the eccentric and the crank are **always** at an angle of 90 degrees to each other. When the valve and eccentric are **direct** connected, the eccentric **leads** the crank, but when a reversing rocker arm is used, as it reverses the motion, then the eccentric **follows** the crank.

In Fig 143 the piston is shown at the beginning of its stroke, the engine being on center, but as this valve has **both** lap and lead, it is no longer in a central position covering equally both steam ports as before. While the crank is still in a horizontal position, as shown in Fig. 142, the eccentric has moved from its vertical position to the right, so that it no longer is at a right angle to the crank, but now forms an **obtuse** angle. The **distance** that the eccentric has been moved forward or **advanced**, is equal to the lap and lead that have been given the valve, and this angle is therefore called the **angle of advance**.

In Fig. 144, the angle A. B. C. is the angle of ad-



Position of Crank and Eccentric, When Valve Has Lap and Lead.
Fig. 143.

vance, in which B. C. shows the position of the eccentric.

If there were **no** lap or lead, the eccentric would occupy the vertical position A. B., but in order to make the edge of the valve coincide with the edge of the port, it was necessary that the eccentric be moved forward until it occupied the position B. D. In order to allow for **lead**, it was necessary that it be moved still **further** forward until it occupied the position B. C., at which point it is fastened securely to the shaft of the engine, and remains so fixed until some future time when it may be desired to change the point of cut off, or the lead.

The angle A. B. D. is called the **angle of advance of the eccentric**, and the angle B. D. C. is called the **angle of lead**, so that the angle of advance is equal to the **sum** of these two angles.

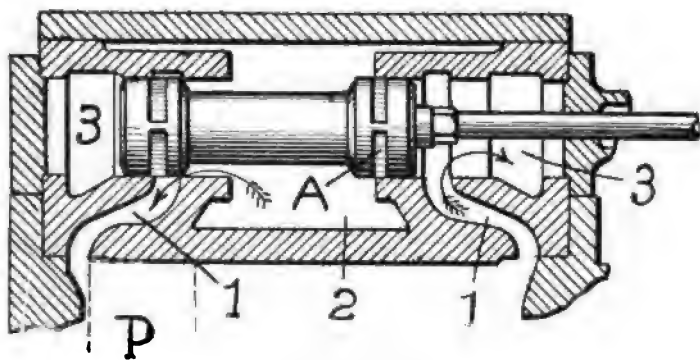
The angle C. B. R., which is the angle between the crank and the eccentric, is therefore equal to the angle of advance, plus 90 degrees.

In Fig. 144—(1) the eccentric and crank are shown by the heavy black lines, the line B. C. representing the **radius** of the eccentric.

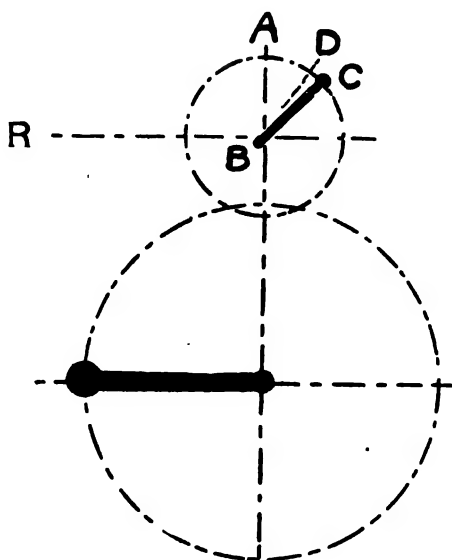
Effects of Lap.—If the outside lap shown in Fig. 143 had been greater, as the valve is moving towards the left, the steam port would have been closed **sooner**, and therefore the cut off would have been **earlier** in the stroke, as the piston is moving to the right.

If on the contrary the outside lap had been **less**, then the steam port would have opened earlier and the cut off would have been **later**, causing less expansion of the steam, and a higher pressure at release.

If we **increase** the inside lap of the valve, the exhaust ports as can be seen in Fig. 143, will open later, making compression to begin **earlier**.



A Piston Valve.



Angle of Advance.

Fig. 144—(1).

We therefore see that if we keep the angle of advance the same, increasing the outside lap causes an earlier cut off, while decreasing the amount of the outside lap, will make a later cut off. The effect of an **earlier** cut off is to get greater expansion out of the steam, and hence greater economy.

Also, that increasing the **inside** lap, causes greater compression and a later release, while decreasing the inside lap decreases the compression and makes the release earlier.

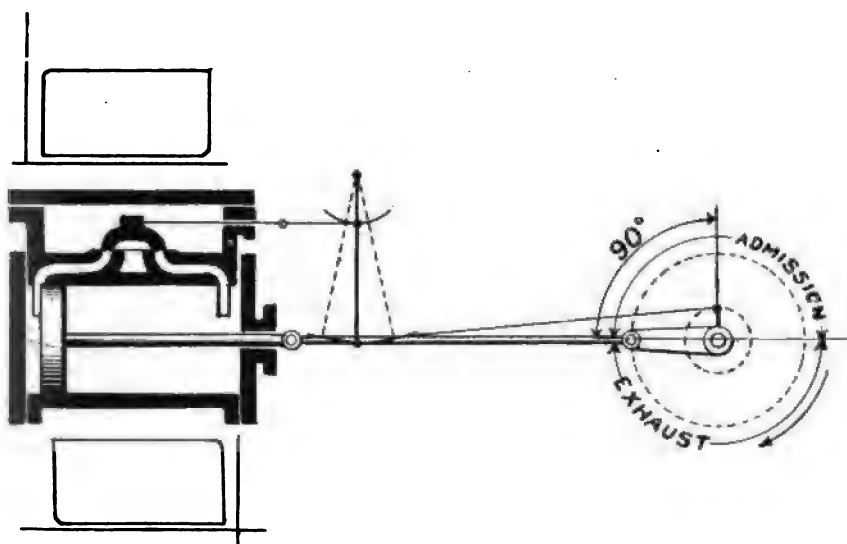
Increasing or decreasing the **inside** lap does not effect the cut off, and hence the expansion; but it alone effects the **release** and **compression** of the steam.

Shifting the eccentric **ahead** or forward, makes all the events in the stroke come **earlier**, and moving it **backwards** retards all the events. Lengthening or shortening the valve stem has no effect on the action of the valve, its only effect being to make the lead or cut off greater on one end than on the other.

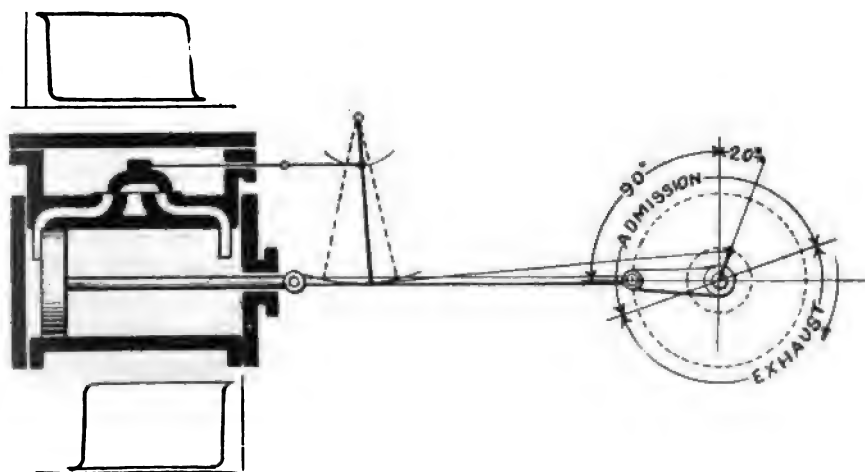
In Fig. 144—(2) is shown position of eccentric, and the **angle of advance**.

We therefore see that the **four** important events in the **distribution** of the steam which occur in every revolution of the engine are: (1) admission; (2) cut off; (3) release; (4) compression.

- **Admission** starts the moment the steam port is uncovered, and continues up to the point of the **cut off** of the steam. **Release** begins when the exhaust port is opened to the **exhaust** chamber, and continues until it is closed, when **compression** begins and ends with the admission of fresh steam on the return stroke. Expansion of the steam therefore continues from the instant of cut off to the release of the steam by the opening of the exhaust port.



When Valve Has Neither Lap nor Lead.



When Valve Has Lead.

Position of Crank and Eccentric, Showing Angle of Advance.

Fig. 144—(2).

Direct and Indirect Valve.—A slide valve is said to be **direct** when it opens the left port by moving to the **right**, which makes the valve take its live steam over its **outside** edge, and exhaust past the **inside** edge.

A valve is said to be **indirect** when it opens the left steam port by moving to the **left**, and closes it by moving to the **right**. This valve therefore takes its live steam over its **inside** edges, and exhausts past the **outside** edge of the valve.

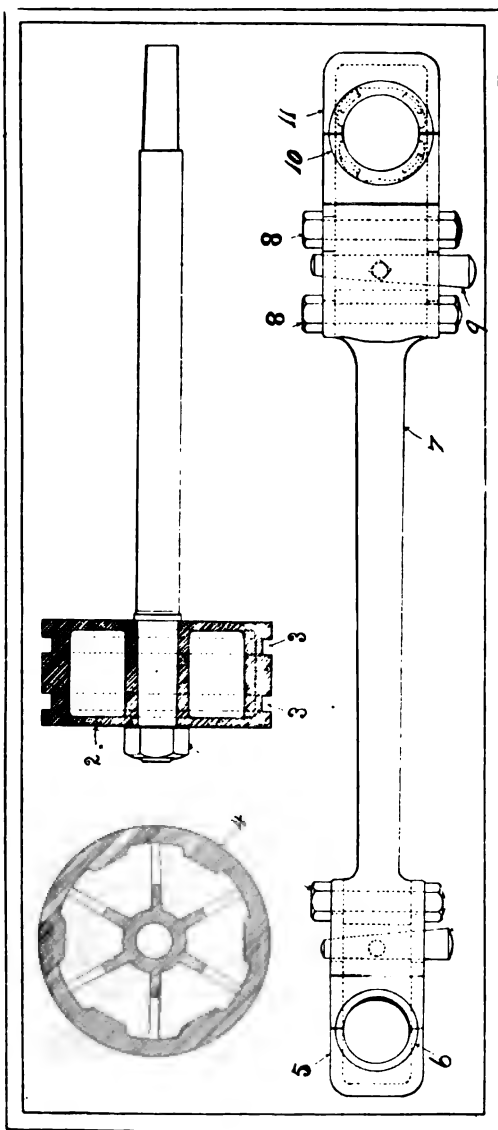
The plain slide valve which has been described in above figures, is therefore a **direct** valve, as it opens the left port by moving to the right, admitting steam past the outside edge, and exhausting past the inside edge.

The **piston** valve is an example of an **indirect** valve.

The Piston Valve.—The valve shown in Fig. 144 is a **piston** valve. It consists of a hollow cylinder moving back and forth in a cylindrical valve seat. The ports 1 extend clear around this valve. The live steam is admitted into the central chamber 2, and the exhaust steam escapes out of the two ends 3, 3. As shown in the figure, the engine is on its center, the piston P about to start to the right, and the valve therefore is moving to the **left**, thereby uncovering the **left** steam port, and thus allowing the steam to enter past its **inside** edge, making it an **indirect** valve.

To **increase** the admission of live steam, steam passes into the center of the valve through the channel A, and thence out into the left port. The **exhaust** steam escapes past the **outside** of the valve through the **right** port 3.

A piston valve is not **necessarily** an indirect valve, as these valves are often made **direct** acting, being then treated exactly as an ordinary slide valve. Such direct



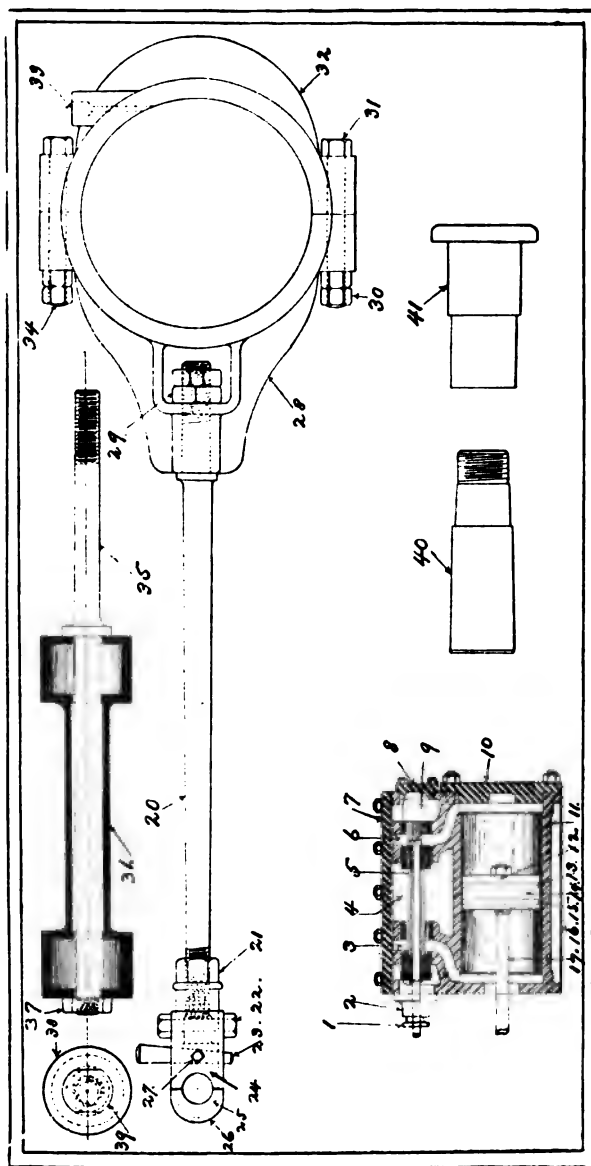
Section of Connecting Rod, Piston Rod and Piston.
Fig. 145.

acting piston valves are not made hollow, otherwise, their construction is the same as the slide valve.

In Fig. 145 is shown a section of connecting rod, piston rod and piston.

In Fig. 146 is shown a sectional view of a steam chest and cylinder, showing a piston valve. Also, many of the minor parts of an ordinary engine is shown, the numbers indicating same corresponding to the numbers in the figure.

1. Valve stem stuffing box gland.
2. Valve steam stuffing box.
3. Steam port.
4. Exhaust chamber.
5. Piston valve.
6. Steam port.
7. Steam chest cover.
8. Valve chest head.
9. Steam chamber.
10. Cylinder head.
11. Cylinder.
12. Piston follower.
13. Piston ring.
14. Piston.
15. Piston ring.
16. Cylinder casing.
17. Piston rod.
20. Eccentric rod.
21. Adjusting nut.
22. Bolt for fastening the strap and brasses on valve stem end of eccentric rod.
23. Key.
24. Brass boxes.
25. Brass boxes.
26. Eccentric rod strap.



Section of Steam Chest and Cylinder, Showing Piston Valve,
Eccentric and Rod.
Fig. 146.

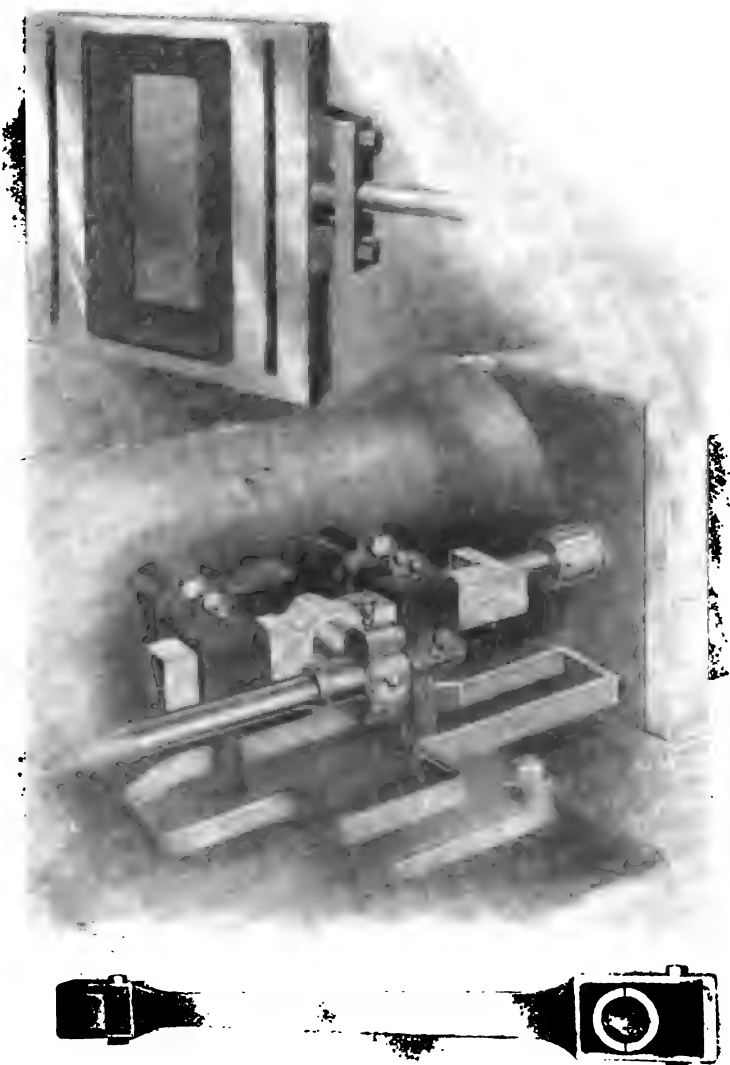
27. Set screw.
28. Eccentric strap.
29. Lock nut.
30. Lock nut.
31. Lock nut.
32. Eccentric strap.
33. Oil cup for eccentric.
34. Eccentric strap bolt.
35. Valve stem.
36. Piston valve.
37. Valve stem nut.
38. End view of piston valve.
39. Valve stem nut.
40. Wrist pin.
41. Crank pin.

Travel.—The **travel** of the valve is the total distance that it moves, and is equal to twice the throw of the eccentric. A valve with lap must be given more travel than one without lap so as to open fully each port to steam. Without lap the travel is equal to **twice** the port openings, as there are two ports to uncover. With lap, the travel is equal to twice the port openings **plus** the lap.

Increased travel means increased throw of the eccentric, and therefore a larger eccentric.

Lead does not effect the travel of the valve, as that is included in the port opening to which is added the lap of the valve.

Setting the Slide Valve.—Place the engine on a **dead center** and give the valve the necessary amount of lead; then turn the engine to the other dead center, and see if the valve has the **same** amount of lead; if so, it is properly set, but if the lead is **not** the same then the valve must be **adjusted** by means of the **valve rod** and nuts, so as to make the lead of both ends equal.



Slide Valve, Connecting Rod and Valve, and Eccentric Connection.
Fig. 147.

To Place Engine on Center.—Place the engine so that the piston has nearly completed its outward stroke, and opposite some point on the crosshead make a mark upon the guide, as shown at E in Fig. 136.

Against the rim of the wheel place a pointer, as at C, and make a mark upon the wheel opposite this pointer when the crosshead is in line with the mark E upon the guide. Now turn the engine over until the crosshead is again in the same position on its **downward** stroke. This will bring the crank as much below the center as it was before above it, and the point F on the fly wheel will be opposite the pointer, and must be marked. Divide the distance between F and C accurately and **midway** between them, mark the point H. Now bring H opposite the pointer, and the engine will be upon the **true center**.

Fly Wheel.—There are two instants in each revolution of the crank when the directions of the crank is in line with the connecting rod, and the position of the crank pins at those instants are called **dead points**, as the piston is momentarily at a stop in order to change its direction when it reaches these points. In order to diminish the irregular action caused by the existence of these dead points and also to carry the engine over these centers, a **fly wheel** is used, which prevents such fluctuations in speed as would be caused by these centers. The momentum of the fly wheel carries the shaft around until the piston can again be acted upon by the steam. The heavier the fly wheel, therefore the steadier will be the motion, but it is undersirable to use larger wheels than are absolutely necessary, on account of the cost of the metal, the weight on the bearings and the danger from bursting.

If the engine must be stopped and reversed fre-

quently, it is better to use two or more cylinders connected to the same shaft, and in this way the use of a fly wheel can in many instances be avoided. When two cylinders are used, the cranks are placed at such angles that when one is exerting its minimum force, the other is exerting its greatest power. In this way the engine can be carried over the dead centers without the expense and inconvenience of having a fly wheel.

The fly wheel of an engine in addition to serving the purpose of a balance wheel, may also be used as a belt wheel and a governor wheel. As a balance wheel it must have, as we have seen, considerable weight to carry the engine smoothly over the centers by absorbing or giving out sudden excess and shortage of power.

As a **belt wheel** it is used to deliver the power of the engine to the line shaft through the belt, and as a **governor wheel** it serves to carry the automatic governing mechanism.

When it is necessary to use an unusually heavy fly wheel, or one located at a distance from the engine frame, an extra bearing is used to carry the outside end of the shaft, so as to relieve the strain on the main bearing.

To **reverse the motion** of a slide valve engine place the engine on the center, noting the amount of the **lead** on the valve. Then slacken up the set screw of the eccentric and turn it ahead on the shaft, that is, the same way it has been running, until the valve has moved to the extreme of its travel, when it will be exactly opposite its original position. Lastly, move it back until it has the same lead as before and tighten the set screw.

Lining an Engine.—First **strip** the engine. To do this take off both cylinder heads, then take out the follower-head, piston rings and bull ring, and disconnect the piston from the crosshead and crank pin.

Now take a slotted stick and place it on one end of the studs on the end of the cylinder furthest from the crank. Draw a fine string over the stick and through the center of the cylinder, and attach it to an upright stick fastened at the other end of engine bed or the floor. Take a thin stick, not more than $\frac{1}{4}$ of an inch thick, and about $\frac{1}{2}$ inch shorter than the diameter of the cylinder. Stick pins in each end of the stick, so that the pins can be easily forced in or drawn out to suit the adjustments. With this stick, **center** the line at each end of the cylinder from four opposite sides by moving the stick around in the counter bore of the cylinder. While only two adjustments are necessary to get the string in the center of the cylinder, it is best to measure around from four opposite sides in order to secure accuracy.

This line is then the center line of the engine, and all other parts of the engine have to be adjusted by it.

The shaft should be **first** adjusted by placing same at right angles with this line. This is done by using a vertical line. It can then be **leveled** by placing a level on the shaft.

The **guides** are adjusted by laying a **straight edge** across the face of the lower guide, and measuring the distance from the straight edge to the center line on both ends of the guides. Should there be any difference, it must be adjusted by adjusting the guides.

In this way all parts of the engine are adjusted, or lined, including its frame or bed.

Horse Power of an Engine.—The unit of horse power is the **foot pound**, by which is meant one pound of force exerted through one foot of space. **One** horse power is the raising of 33,000 foot pounds per minute, or 550 foot pounds per second.

Rule.—To find the horse power of an engine, multiply the **area** of the piston in square inches by the **average** pressure of the steam in pounds, and this by its piston speed in **feet** per minute, and divide the product by 33,000.

Formula.—The formula therefore to determine the horse power of an engine is, viz.:

$$\text{H. P.} = \frac{P \ L \ A \ N}{33,000}.$$

In this formula, P=the average or mean effective pressure in pounds per square inch. A=area of piston in square inches. L=length of stroke in feet. N=number of strokes per minute.

Example.—What is the horse power of an engine with a piston 16 inches in diameter, a stroke of 30 inches, and running at 150 revolutions per minute, with an average steam pressure of 55 lbs., assuming that the average pressure is the **same** on both sides of the piston?

Solution.—To find the **area** of the piston, **square** the diameter and multiply by the fraction .7854. Therefore, for a diameter of 16 inches, the area would be equal to 201 inches.

To find the **piston speed**, the stroke must be multiplied by **twice** the number of revolutions, as the piston travels twice the length of the cylinder during each revolution of the engine.

Therefore substituting in the above formula,

$$\text{H. P.} = \frac{55 \times 2\frac{1}{2} \times 201 \times 2 \times 150}{33000} = 251.25 \text{ nominal horse power.}$$

As most engines do more work at one end of the

cylinder than at the other end, for **accurate** work the average pressure must be ascertained for each end of the cylinder. Also, on account of the piston rod's connection to one side of the piston, the area is not the same for both sides, and each side must be figured **separately**. The area of the piston rod must then be deducted from the calculation, as the surface of the rod not being utilized for the effective working pressure of the steam, must be deducted.

Mean Effective Pressure.—Only in engines that take steam **full stroke** does the boiler pressure act upon the piston during the entire stroke.

In all other engines, the boiler pressure acts upon the piston during only a part of the stroke, since from the instant of the cut off of the steam, the remainder of the stroke must be made by the expansive force alone of the steam; and as the piston moves forward and the steam cools, this pressure rapidly **decreases**.

In order to determine the amount of work that the engine will perform it is therefore necessary to find the **average pressure**, that is, the **mean effective pressure** as it is called, during the **entire** stroke of the piston.

The mean effective pressure is therefore the average forward pressure on the piston less the back pressure, that is the **net** pressure of the steam acting upon the piston during each stroke. This average forward pressure depends upon the initial pressure in the cylinder, and upon the point of cut off. The initial pressure will depend upon the boiler pressure, and the point of cut off will depend to a large extent upon the type of engine. The back pressure will depend upon whether the engine is a condensing or non-condensing engine.

To Determine the Mean Effective Pressure.—This pressure is usually determined by taking an indicator

card of the engine. This diagram, or card, which is taken during one or more revolutions of the engine will show the **exact pressure** acting on the piston throughout the entire stroke, and from which the mean effective pressure can be calculated.

The device or instrument used for making this diagram, or cards, is called an **indicator**, and it will be described in a later chapter.

Throttling and Automatic Engines.—The ordinary slide valve engine, as has above been described, is what is known as a **throttling engine**, as its regulation is controlled by means of a throttling valve. With a throttling engine the point of cut off is **fixed**, and the speed is regulated by a throttling valve in the steam pipe, called the governor valve, which admits more steam as the load increases and less as it decreases. This **wire-draws** the steam as it is called, which is not only wasteful of fuel, as the full pressure of the boiler cannot be utilized, but it also prevents any perfect regulation of the speed of the engine.

Automatic Engine.—This engine has a **variable** cut off, which permits full boiler pressure to be utilized, as the steam is cut off the moment a sufficient amount has been admitted to the cylinder to complete the stroke, allowing the remainder of the stroke to be completed by its expansion.

Classes.—All engines are divided into these **two great classes**, the chief difference being in the principle of the **regulation** of the steam supply.

Uses.—The first class, or the throttling engine, is mostly used for small mills and factories, on account of its simplicity and low first cost. The second class, or the automatic engine, while it is much more complicated, is much more **economical** in the use of steam, and

is therefore used in larger plants, or wherever fuel is expensive.

To Increase Horse Power of an Engine.—The horse power of an engine can be increased in three different ways, viz.:

(1) By increasing the **diameter** of the governor pulley, which increases the **speed** of the engine, and thereby the power.

(2) By a **later** cut-off, which requires a new valve, and a change in the eccentric and travel of the valve.

(3) By increasing the boiler pressure.

While the **power** of the engine is increased, the **amount** of steam used, is also increased.

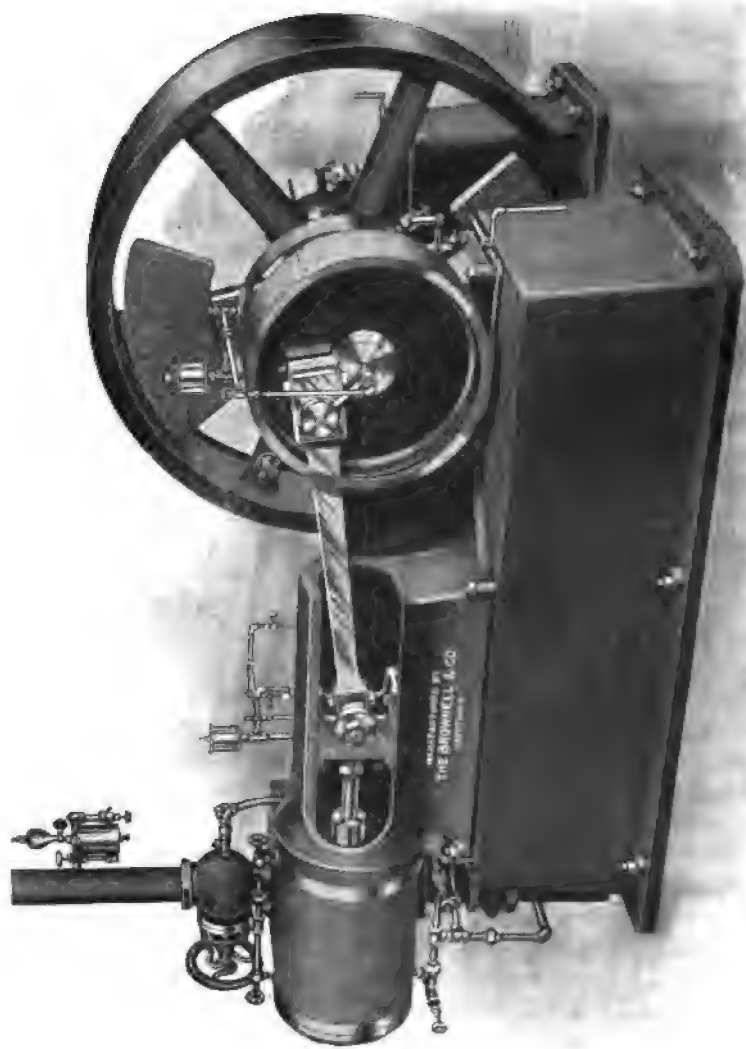
Right Hand Engine.—This is an engine, the fly wheel of which is to the **right** when looking at the engine facing the cylinder.

Running Over.—An engine is said to "**run over**" when the top of the wheel runs away from the cylinder, and to "**run under**" when the top of the wheel runs **to-**
toward the cylinder.

Most engines are built to "**run over**," as the pressure of the cross-head is then always **downward** upon the guide. When the engine "**runs under**," the thrust of the cross-head is then upon the **top** guide on both the outward and inward strokes, which is likely to cause the cross-head to **lift** when subjected to the thrust, and then fall by its own weight on the centers, making the engine pound.

THE BROWNELL SLIDE VALVE ENGINE.

Type.—As will be seen from Fig. 148, this engine is of the **self-contained side-crank type**, that is, the outer bearing is cast solid as a part of the bed. This is a feature of great importance, as the engine can be shipped in perfect alignment and set in position ready for running in less time than required for other types of engines. Furthermore, this work requires no expert me-



The Brownell Slide Valve Engine, with Shaft Governor.
Fig. 148.

chanic, as all fine adjustments are made at the factory before shipment.

Proportions.—The crank shaft is made extra heavy, the length of main bearing is approximately twice the diameter of the shaft, and the length of outer bearing is approximately three times the diameter of the shaft, and all other parts are proportionately large.

Material.—The crank shaft, pins and piston rod are hammered steel, the connecting rod is a solid steel forging, the main bearings are lined with first-class babbitt and scraped to a true fit. The cross head is of the Corliss type, and has babbitt lined adjusting shoes top and bottom.

SPECIFICATIONS FOR AN ORDINARY SLIDE-VALVE STEAM ENGINE.

We hereby propose to furnish you with slide-valve steam engine manufactured by, in strict accordance with the following detailed specifications:

Size and Horse Power.—The engine shall be our slide-valve (self-contained or detached) side-crank type with overhanging cylinder inches diameter and inches stroke. With .. pounds boiler pressure and running a.....revolutions per minute the engine will developI. H. P.

Valve.—Valve to be accurately fitted and scraped to its seat, and guaranteed steam tight, with ample steam and exhaust ports.

Piston.—The piston to be of the solid type with spring packing rings.

Crosshead.—Crosshead to be of the Corliss type, with bored guides and babbitt lined adjustable shoes of liberal area, top and bottom.

Connecting Rod.—The connecting rod to be a solid steel forging with ends mortised to receive boxes. The box at crosshead end to be phosphor bronze, at crank end of cast iron lined with genuine babbitt.

Crank Shaft.—The crank shaft to be of the best quality hammered steel inches diameter, turned true and nicely finished, and free from flaws or other imperfections.

.....
Journals.—The bearings to be adjustable and lined with the genuine babbitt metal, accurately scraped to true bearing surface. Crank bearing inches long, outer bearing inches long.

Wheel.—Band fly wheel to be inches diameter and inches face. Weight about pounds.

Pins and Rods.—The crank pin, crosshead pin, valve rod and pin, and piston rod to be of hammered steel, highly finished and properly proportioned for the required service.

Cylinder Jacket.—The cylinder to be provided with neat sheet steel jacket.

Trimmings.—Engine to be furnished with first-class throttling governor, with automatic stop, throttle valve with nipple, sight feed cylinder lubricator, full set of sight feed oil cups, centrifugal oiler for crank pin, cylinder drip valves and set of wrenches.

.....

Speed and Hand.—Engine to be hand and to run at revolutions per minute.

Finish.—Engine to be primed, rubbed down and fin-

ished in a hard varnish paint, green or maroon, at option of purchaser. All necessary parts to be polished.

Guarantee.—We guarantee the above engine to be equal in efficiency and durability to any engine of its type and class manufactured. We further guarantee all parts free from defects of design, material or workmanship.

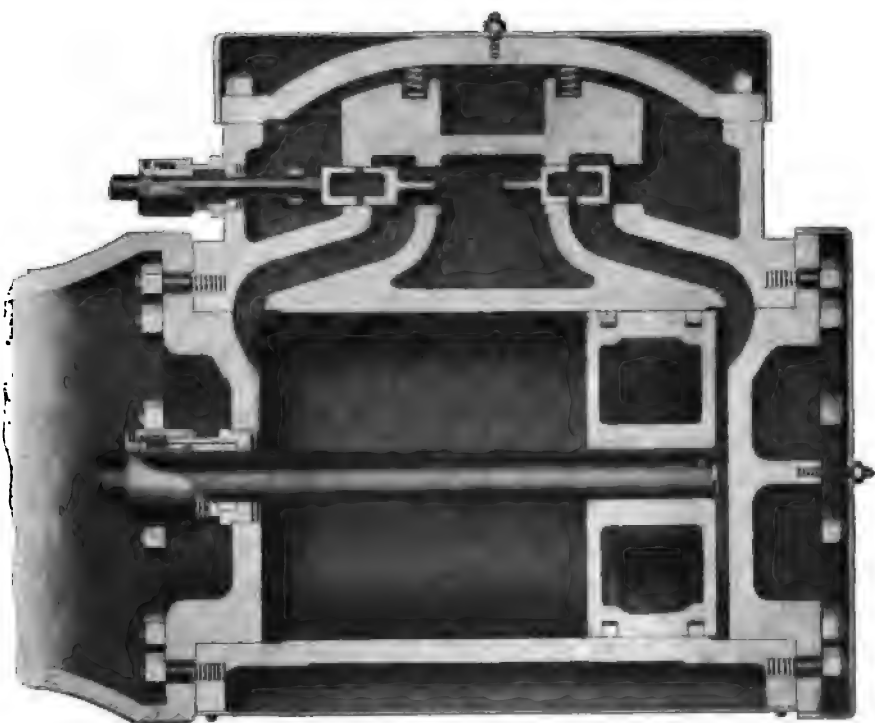
Test.—Before leaving factory engine will be thoroughly tested under steam and indicated to properly set valve and adjust all parts under actual working conditions.

Drawings.—The necessary drawings for preparing foundation and erecting engine will be furnished free of charge.

THE BROWNELL AUTOMATIC ENGINE.

Frame.—The frame of engine, as seen from Fig. 148, is a modification of the well known Tangye type, the principal change being in the adoption of the Corliss type of crosshead with circular guides. The main bearings are unusually liberal in proportion, and are provided beneath with oil reservoirs, from which the bearings receive a liberal and continuous supply of oil whenever engine is in motion.

Governor.—Referring to Fig. 148, it will be seen that the governor consists essentially of the single weighted arm, swinging on a pivot pin. Fastened to this arm is the eccentric which drives valve. As the weight arm assumes different positions due to changes in load, the center of eccentric is brought nearer to or farther from the shaft center, thereby regulating travel of valve and admission of steam, in proportion to work required. There is an entire absence in this governor of the usual



Sectional View of Balanced Slide Valve.
Fig. 149.

complication of links, dash pots and other interlocking devices.

Valve.—The valve shown in Fig. 149 is a thin rectangular ported casting, finished on both sides to an exact thickness. This valve works between the valve seat and a heavy pressure plate, which removes the pressure from its back, making it perfectly balanced. The weight of the valve causes it to wear down slightly, but this wear can cause no leak of steam, as is the case with the piston valve. This construction necessarily requires the greatest skill and accuracy in its production, making it much more expensive than other forms. Its great advantages, however, fully justify its increased cost. Provision is also made for relief in case of a charge of water getting into cylinder, thereby preventing an accident.

Cylinder.—The cylinder is cast from a special mixture making a close-grained iron which takes a high polish and which has great tensile strength. The cylinder is bolted direct to engine frame, the end of frame forming the front cylinder head.

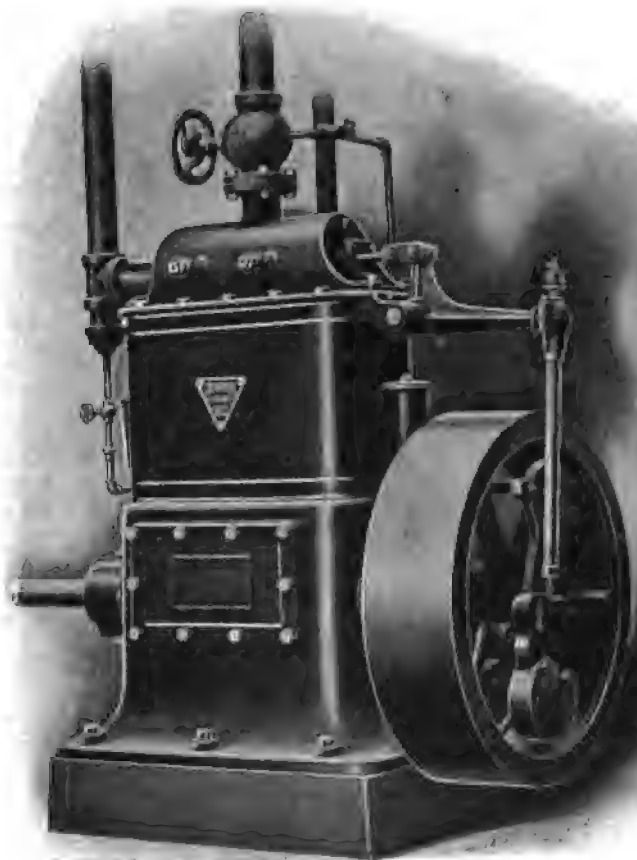
Piston.—The piston is a single casting, cored very thin, and is braced with ribs to make it strong enough for any legitimate strain. It is shrunk on rod, and rod riveted over, on 10 and 11x12 engines, while on larger ones, it is held in place by a nut on end of rod. The wearing surface is very liberal. The piston is packed by two elastic cast iron rings, one near each end, while another ring of babbitt is poured in chamber in center.

In Fig. 147 is shown views of the valve, connecting rod and eccentric connection.

THE JUNIOR VERTICAL ENGINE.

Fig. 150.

Construction.—From an inspection of the sectional view shown in Fig. 151, it will be seen that the Junior



Front View of the Junior Vertical Engine.

Fig. 150.

Engine consists in general of a pair of vertical cylinders bolted to the top of an enclosed crank case, the latter serving the double purpose of a rigid pedestal for the engine and a receptacle for the lubricating material.

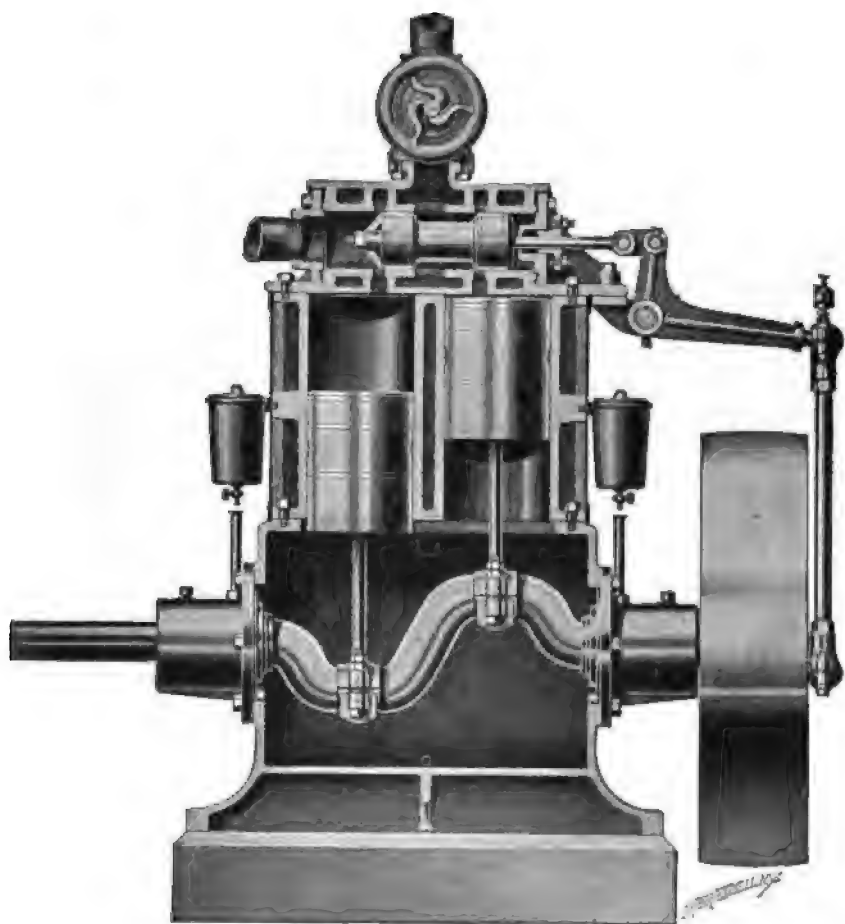
Steam Chest.—The steam chest, containing the single **piston valve** for effecting the steam distribution, is bolted horizontally across the top of the cylinders, motion to the valve being communicated through a bell crank from the governor carried on one of the fly wheels. Spring relief valves in the front side of the steam chest, communicating with the ports leading to the cylinders, furnish ample protection against shocks from sudden charges of water coming over through the steam pipe.

Bolted to the ends of the crank case are the crank case heads, which serve to support the main bearing shells and at the same time to cover openings in either end of the crank case to permit the introduction or removal of the shaft.

Main Bearings.—The main bearings are plain cast iron cylinders lined with genuine babbitt metal. They are turned on the outside concentric with the bore, to fit accurately into the crank case heads, where they are secured by set screws.

The pressure on the main bearings being always downward, when the babbitt is worn nearly through on the lower side the upper surface is still intact. The shells may then be turned over, bringing the unworn part into service and making the bearings for all intents and purposes as good as new.

Piston.—The piston, which also serves the purpose of crosshead, is of the well-known trunk pattern, very long in proportion to its diameter. A long piston is less liable to leak steam than a short one, and it does not



Sectional View of the Junior Engine.

Fig. 151.

allow the cylinder to wear larger in the middle. The packing consists of three cast iron spring rings.

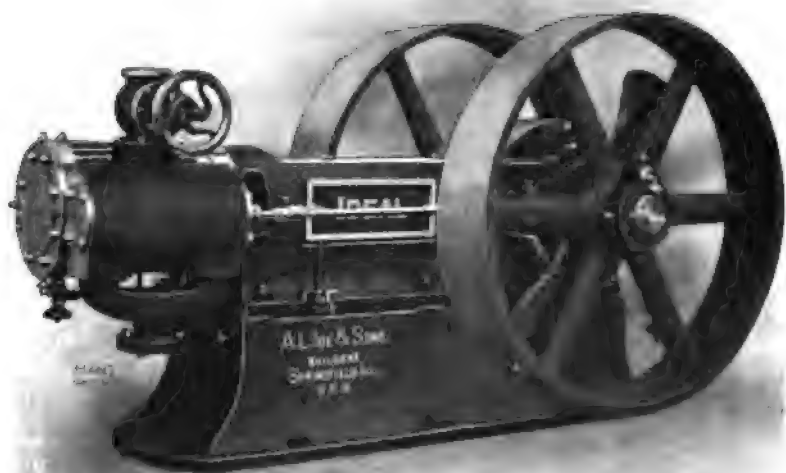
The piston wrist pin, with which the upper end of the connecting rod engages, is case-hardened and ground to a perfectly true cylindrical surface.

Valve.—The action of the valve will be easily understood from the sectional view in Fig. 151. Steam entering fills the annular space surrounding the neck of the valve. When the parts are in the position shown, the valve is moving toward the left, establishing communication between the steam space and the left hand cylinder through the left port, the left hand piston just starting on its downward stroke. The right hand end of the valve has begun to uncover the right port, so that the exhaust can pass up and through the valve, which is **hollow**, to the exhaust pipe. As the revolution progresses, the valve reaches the limit of its travel toward the left and starts back, covering the left port again, at a point determined through the governor by the load, allowing expansion to take place in the left hand cylinder. Continuing its travel toward the right, the valve covers the right port, so that a portion of the exhaust steam is compressed to fill up the clearance spaces. A little later, and just before the revolution is half completed, the left hand end of the valve uncovers the left port, so that the exhaust may have free exit when the left hand piston begins its upward stroke. A similar cycle of operations now occurs in opposite cylinders, completing the revolution.

THE IDEAL AUTOMATIC ENGINE.

Fig. 152.

Construction.—The accompanying cuts shows this engine as it appears with the standard equipment,



The Ideal Automatic Engine.

Fig. 152.

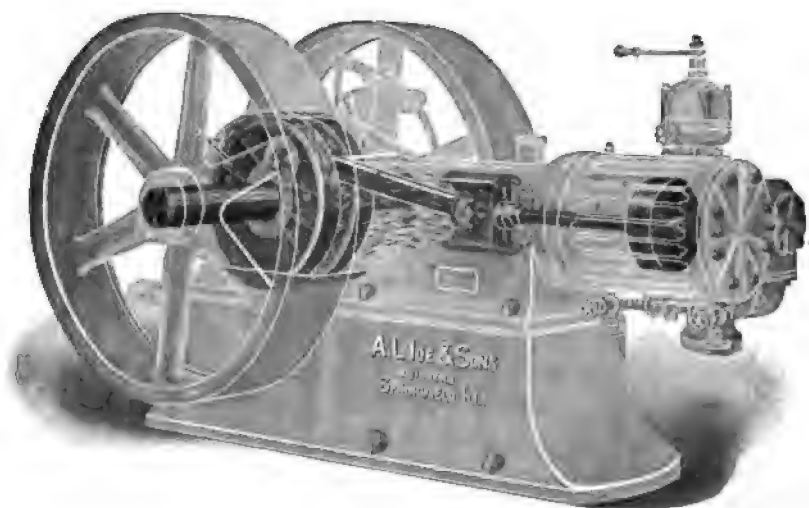
and thence flows in streams through suitable channels to the main bearings, crank-pin and eccentric; from all of which distributive points the oil returns by gravity to the oil reservoir, so to be used over and over again.

Valve Mechanism.—Fig. 154 shows the valve mechanism of single engine. The valve is driven centrally in a direct line with the eccentric, with the intervention of only one joint, and without the use of slides, rocker-arms, offset or any of the other complications so generally employed.

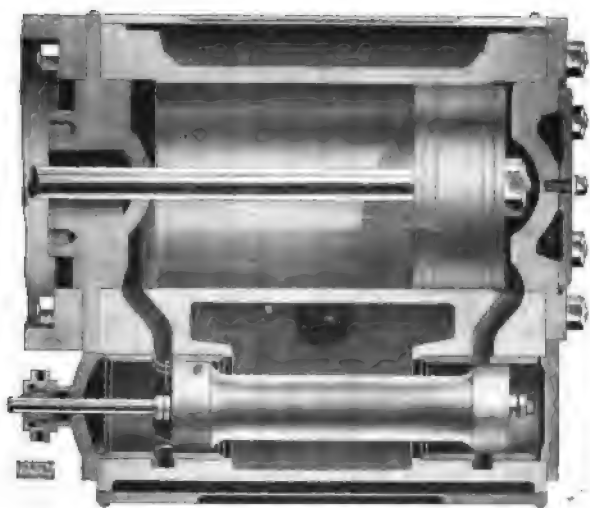
Adjustable Ball-Joint.—The one joint in the valve-driving mechanism is formed by the combination of a hard steel ball attached to the eccentric-rod working within a bronze socket attached to the valve-rod. It is adjustable by means of a set-nut, which fixes the distance between the two halves of the socket.

Compound Cylinder and Valves.—Fig. 197 shows valves of the compound engine. The cylinders of Ideal Compound Engines are arranged tandem-wise, the low-pressure cylinder being bolted to the end of main frame, and the high-pressure cylinder immediately to the end of low-pressure cylinder. Steam from the high-pressure cylinder has a short, direct passage into the low-pressure cylinder, without suffering loss of heat by passing through connecting pipes or receiver.

Types of Valves Used.—The high-pressure cylinder has a **hollow piston valve**, and for the low-pressure valve in order to bring it into line with the high-pressure valve and reduce clearance spaces to a minimum, has been adopted a **flat balanced valve**, traveling under a cover and so arranged that steam is admitted through two ports simultaneously, thus giving a quick and wide opening at the beginning of the stroke.



The Ideal Self-Oiling System.
Fig. 153.



Sectional View of the Ideal Piston Valve.
Fig. 154.

and thence flows in streams through suitable channels to the main bearings, crank-pin and eccentric; from all of which distributive points the oil returns by gravity to the oil reservoir, so to be used over and over again.

Valve Mechanism.—Fig. 154 shows the valve mechanism of single engine. The valve is driven centrally in a direct line with the eccentric, with the intervention of only one joint, and without the use of slides, rocker-arms, offset or any of the other complications so generally employed.

Adjustable Ball-Joint.—The one joint in the valve-driving mechanism is formed by the combination of a hard steel ball attached to the eccentric-rod working within a bronze socket attached to the valve-rod. It is adjustable by means of a set-nut, which fixes the distance between the two halves of the socket.

Compound Cylinder and Valves.—Fig. 197 shows valves of the compound engine. The cylinders of Ideal Compound Engines are arranged tandem-wise, the low-pressure cylinder being bolted to the end of main frame, and the high-pressure cylinder immediately to the end of low-pressure cylinder. Steam from the high-pressure cylinder has a short, direct passage into the low-pressure cylinder, without suffering loss of heat by passing through connecting pipes or receiver.

Types of Valves Used.—The high-pressure cylinder has a **hollow piston valve**, and for the low-pressure valve in order to bring it into line with the high-pressure valve and reduce clearance spaces to a minimum, has been adopted a **flat balanced valve**, traveling under a cover and so arranged that steam is admitted through two ports simultaneously, thus giving a quick and wide opening at the beginning of the stroke.



The Ideal Inertia Governor.
Fig. 155.

Details of Valves, etc.—The cover of this valve is held in place by springs, and will lift and prevent excessive pressure in the cylinder from water or other causes. Both valves are perfectly balanced, and with full boiler pressure can be moved by hand with ease. Stuffing boxes between the two cylinders are dispensed with entirely, being replaced by a long sleeve of anti-frictional metal. This sleeve is light, and free to adjust itself central with the rod. Grooves are turned on the inner surface so as to form a water packing.

Durability of Metallic Sleeve.—As the sleeve is free to adjust itself to the rod, the only wear that can come upon it is due to its own weight, which is so little that, with the perfect alignment between cylinder and guides insured by this form of construction, the wear is imperceptible. Experience has proven that, with the length of bushings employed, there is no leakage of steam, the time occupied by the piston in making a stroke being so short and the travel of the rod being opposite to the direction in which steam tends to flow.

Ideal Quick Closing Throttle-Valve.—This specialty shown in Fig. 156 has many attractive features, as well as several positive advantages over the usual form of screw throttle-valve.

It is opened or closed by throwing the lever handle through a quarter turn, which enables the engineer to shut steam off from his engine instantly in case of an emergency. A small bypass valve is for use in warming up the engine and starting it slowly.

No Packing Required.—The valve-stem of both the main valve and the bypass are self-packing; that is, they are equipped with self-seating metallic cones, which avoid the use of wick packing or any other form of destructible packing.



Quick Closing Throttle Used on Ideal Engine.

Fig. 156.

The valve-seat is completely accessible upon the removal of the bonnet.

Ordinary Throttles Source of Annoyance.—A source of great annoyance to the engineer is the common everyday throttle-valve supplied with many automatic engines, owing to the **packing** of the valve stem. This must be done frequently to prevent leakage of steam, oil and water.

Inertia Governor.—In Fig. 155 is shown the governor used on this engine, which is the ordinary form of a Rites inertia governor.

THE CHUSE CENTER CRANK ENGINE.

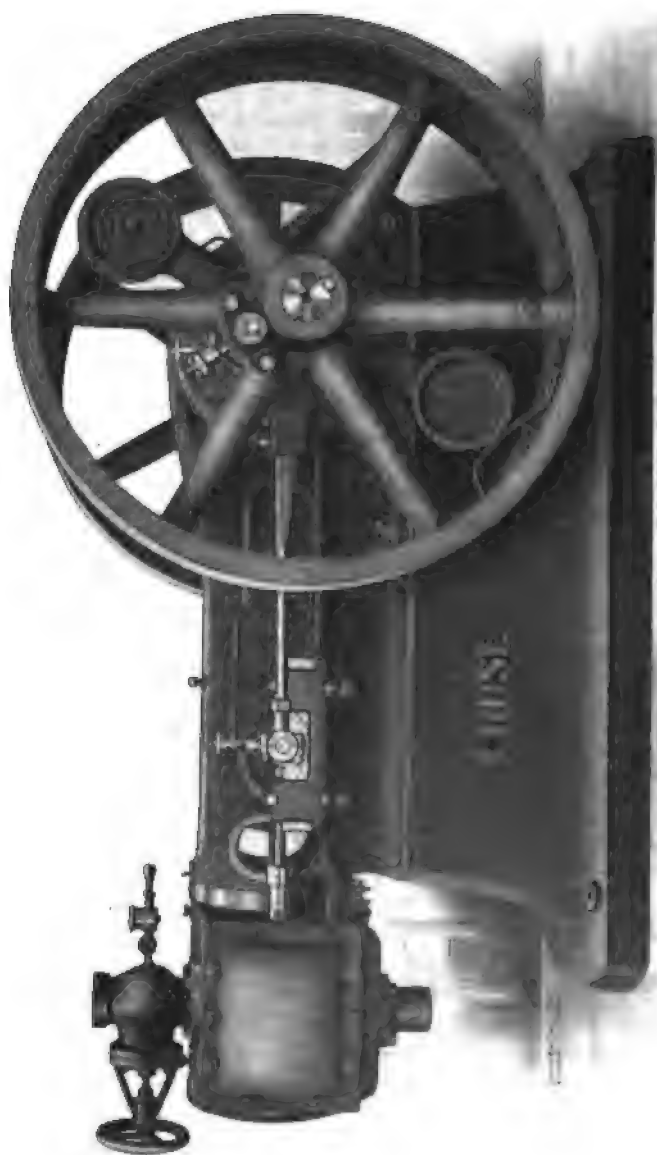
Fig. 157.

Construction.—This engine is a self-oiling, automatic cut-off engine, that presents a good combination for strength, durability and economy.

Frame.—The frame is of the box type and has bored guides, which is best suited to withstand the vibrations and strains upon it, as it forms a column, with the working parts moving down its center axis. It is absolutely oil tight and dust proof, yet it is instantly accessible to all inner parts by means of a crank cover and two large side doors. One of these doors has a slot on the top to accommodate an indicator motion.

Governor.—The "Rites" inertia governor is used on this engine.

Lubrication.—The engine is strictly self-oiling. Every bearing on the engine (with two exceptions) is automatically oiled with the oil contained in the bottom of the crank case. By this means, the journals, crank pin, cross-head pin, guides, eccentric straps and valve stem slides, receive a copious and continual flood of oil,



The Chuse Engine.
Fig. 157.

which after being used, drains back into the crank basin, and is used over again.

This arrangement reduces the wear to a minimum, and makes the engine exceedingly free running and saves the attention necessary to be given to a dozen or more oil cups. Grease cups are used on the governor spindle and valve stem slide ball joint.

A separate chamber in the frame with two stuffing boxes prevent the leakage from the piston rod stuffing box, from mingling with the lubricating oil contained in the engine frame, which preserves the life and efficiency of the oil.

Cylinder.—The cylinder is made of hard close grained iron, of special mixture, and the walls are made thick enough to safely stand reboring several times. It is bolted directly to the frame with ground steam tight joint. The cylinder head is also fitted with a ground joint and is encased in a highly polished cover, that reduces condensation and keeps the nuts from collecting oil and dust.

Very short direct ports are used, which reduce the friction to the passage of steam, and also reduces the clearance to the lowest amount that can be handled by a single valve, variable cut-off engine. The high economy of this engine is largely due to this careful design of the ports and clearance.

Piston.—Is a deep hollow casting well ribbed, but as light as is consistent with proper strength. It is fitted with two snap packing rings. The piston rod is turned from hammered nickel steel bars, and is highly polished. It is fastened to the piston with a lock nut.

The Connecting Rod.—Is solid steel, and is adjusted in such a manner by wedge and keys, that the length of the rod does not change appreciably with wear. The

smaller sizes are fitted with removable hard brass bearings, and the larger sizes are fitted with cast steel shells, lined with the best genuine babbitt.

Cross-Head.—Is a heavy steel casting of compact design, and is fitted with cast iron shoes. The lubrication of the cross-head and guides is so perfect, and the bearing surface so ample, that the wear is scarcely perceptible.

Valve and Balance Plate.—The valve is of the **flat multi-ported pattern**, and is balanced by a heavy balancing plate, held in position by springs and the pressure of the steam. This valve will lift from its seat to relieve any entrained water, thus rendering the use of safety relief valves or diaphragms unnecessary.

The under side of the balancing plate is an exact duplicate of the valve seat, and is so adjusted that it balances the valve perfectly in all positions of its travel.

As both faces of this valve are vertical, and as the valve rides on its lower edge, the seats are relieved from wear due to the weight of the valve, and as the valve is perfectly balanced for steam pressure, very little wear occurs on the valve seats. This construction causes the valve to remain tight longer than any other type.

All valves are fitted to their seats under steam, and all the faces are scraped until they are perfectly true to each other, while under the heating and warping action of the live steam.

Valve Stem Guides.—It is very important that there should be a means of transmitting the angular motion of the eccentric rod to the valve stem in such a manner that it will move through the stuffing box without vibration. A slide is the only means of obtaining this exactly, and a very convenient and substantial slide and bracket is used on this engine.

The T head on the valve stem permits the valve being removed without disturbing the setting of the valve. The lock nuts on the other end of the stem provides a convenient means of outside adjustment, and of fastening it securely to the valve slide.

The stub end on the eccentric connection rod is attached to the valve stem guide by means of a self-aligning ball and socket joint, which adjusts itself to any motion of the eccentric and is lubricated by a grease cup. Oil from the engine frame is fed continuously into the cup shown on top of the slides, and runs down through feed holes to the grooves shown on the upper edge of the slide, and thence through the bearings. A bracket surrounding the bottom of these bearings conducts the waste oil back into the engine frame.

CHAPTER XVI.

GOVERNORS.

Their Use.—A governor is used to **regulate**, or keep constant, the steam power of an engine. As the load on an engine constantly **varies**, some means must be provided by which the steam supply can be regulated in proportion to the load on the engine, so that its power and speed can be kept constant.

Methods.—This is accomplished by the governor on the steam engine in two ways, viz.: (1) by regulating the **pressure** of the steam admitted to the steam chest; (2) by altering the **amount** of the steam admitted to the cylinder, which is done by **varying** the point of cut off of the steam supply. •

Almost all governors depend for their operation upon the **centrifugal force** that is developed in a weight made to revolve around an axis outside of its center of gravity. The weight that is made to revolve, is so suspended that the centrifugal force developed by its rotation is opposed by a counteracting force or resistance, which force is usually a weight or springs, and whether the one or the other is used, determines the **type** of the governor.

Operation.—When the speed of these revolving weights increases, the centrifugal force also increases, and the weight tends to move **outwards** and **upwards**, but this force is opposed by the resistance of **gravity** also acting upon the weight. Should the speed of the engine become **excessive**, this counteracting force is not sufficient to hold the weight in its former path or plane of circuit, and the upward motion of the weight closes the regulating valve, lessening the steam pressure admitted to the steam chest, and in this way decreasing the

speed of the engine. As the speed of the engine **decreases**, the centrifugal force becomes less than the opposing resistance or counteracting force, and the weight is forced **downwards** and towards the axis. This **opens** the regulating valve and admits more steam pressure to the cylinder, thus causing the speed of the engine to increase. This upward and downward motion of the weight is transferred by suitable mechanism, to the valve that governs the flow of the steam to the cylinder.

The Pendulum or Fly-Ball Governor.—This is the earliest and simplest form of the steam governor, being based upon the application of the scientific principle of a revolving pendulum.

In this governor, the centrifugal force is usually counteracted by the force of gravity, and acts upon the principle just described.

Construction.—A pair of heavy iron balls are made to revolve about a spindle, which spindle is driven by the engine. Should the speed of the engine increase, the centrifugal force, as we have seen, also increases, and the balls tend to fly outward and upwards until the controlling or counteracting force is no longer able to hold them in their former circle, and as the balls move outward they act on the regulating valve which **throttles** the steam, should it be a throttling engine; or, if an automatic engine, this motion of the balls is made to cause an **earlier** cut off of the steam in the stroke.

Effect.—The effect of this in the throttling engine, is to decrease the steam **pressure** admitted to the steam chest, and thereby reduce the speed of the engine. Should the engine be an automatic engine, such as a Corliss engine, the effect is to cause an earlier cut off, which reduces the amount of steam admitted to the cylinder, and thereby reducing the speed of the engine.

Should the load on the engine be **increased**, then the steam pressure, or supply, must also be proportionately increased, and as the engine slows down the centrifugal force acting on the iron balls becomes less, causing them to drop and revolve in a smaller circle, thus opening the throttle valve wider and permitting a greater steam pressure, or, a **later** cut off, if an automatic engine. In **either** type of engine, the **speed** and **power** of the engine will be at once increased in proportion to the increased power supplied.

Advantages and Disadvantages.—The disadvantage of throttling the steam is the loss in **efficiency**, as fuel must be burned to keep up the boiler pressure, which at times is so throttled, or obstructed, that its **full force** can not be utilized, and is therefore wasted. This disadvantage is partly offset by the **decrease** in cylinder condensation.

With the variable or automatic cutoff engine, the steam is used continuously under almost full boiler pressure, the **supply** alone being regulated to meet the requirements of the engine. Therefore, the above disadvantage does not exist when this form of governor is used on an automatic engine.

In Fig. 158 is shown the usual form of a pendulum or fly-ball governor. The parts of this governor as indicated by the figures in the cut are as follows, viz.: 1, governor shaft; 2, standard; 3, governor balls; 4 stem swivel; 5, arms; 6, pivots; 7, pulley; 8, gear; 9, stem; 10, bonnet; 11, stuffing box; 12, glands; 13, valve discs; 14, valve seat; 15, stem guard; 16, valve chest flange.

In Fig. 177 is shown a more modern form of a **simple** pendulum governor, which form of governor is much used on Corliss engines. Instead of a single weight, two balls are used. These balls are suspended from a collar

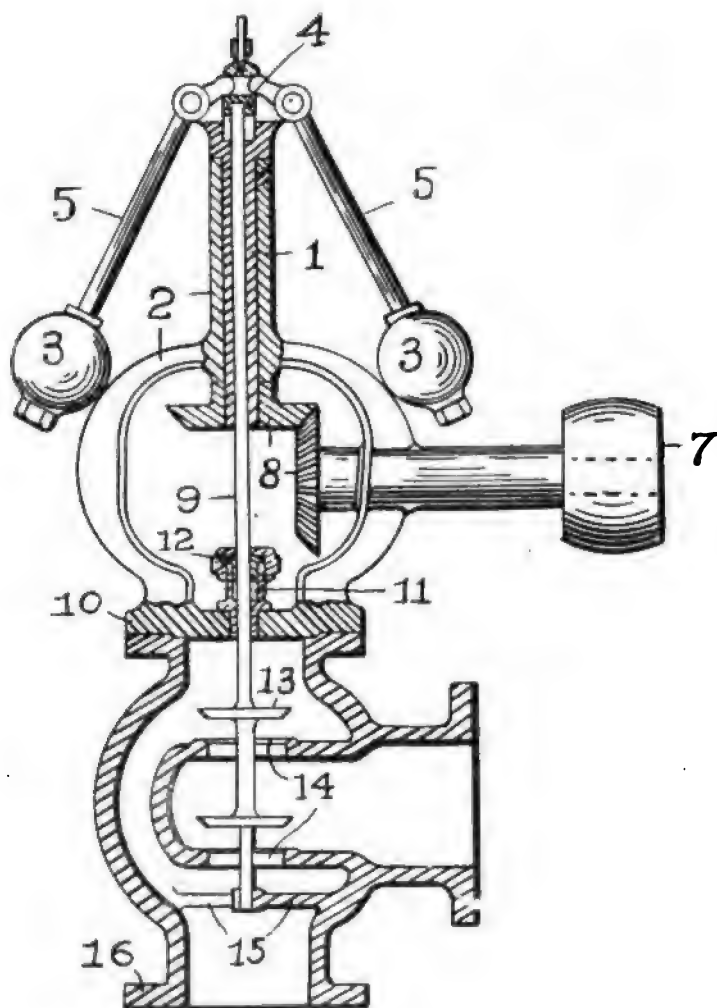
that is fastened to the spindle, and rotates with it. Links connect the arms to which the balls are attached, to a second collar that turns freely on a sleeve, not being attached to the spindle. The sleeve does not rotate, but is **free** to slide up and down on the spindle. When the balls fly outwards, the sleeve is pulled upwards by the links, this motion being transmitted to the valve gear by a connecting rod. To prevent **sudden fluctuations** of the governor, a rod which is connected to the sleeve, operates a piston loosely fitted in a cylinder, called a **dash pot**, which is filled with oil.

The Porter Governor.—This governor is a modification of a simple pendulum governor, whose **sensitiveness** has been much increased by adding to the **range of motion** of the centrifugal weights for a given range in speed. Fig. 159 shows the construction of this governor. The centrifugal weights 1.1 are **small**, and by running them at **high speed** their centrifugal force is comparatively great. In addition to their own weight, the balls must lift the large weight 2, that is made free to slide up and down on the spindle 3, this weight being lifted by means of the links 4.4, the weight 2 revolving with the spindle. At its lower end is attached a collar that gives motion to the lever 6. This lever transmits the motion to the gearing that operates the valve. 7 is a dash pot and 8 a small weight that gives additional adjustment. The governor is driven by a belt from a pulley on the engine shaft that drives the spindle 3, by means of the pulley 1.

THE GARDNER GOVERNOR.

In Fig. 160 is shown this old and standard form of governor. As here shown, it is a **gravity** governor having an automatic safety stop and speeder.

In action, the centrifugal force of the pendulous



Sectional View of a Throttle Governor.

Fig. 158

balls is opposed by the resistance of a weighted lever, the speed being varied by the position of the weight.

The automatic safety stop is very simple in construction. It is accomplished by allowing a slight oscillation of the shaft-bearing which is supported between centers, and held in position by the pull of the belt; a projection at the lower part of the shaft-bearing supports the fulcrum of the speed lever.

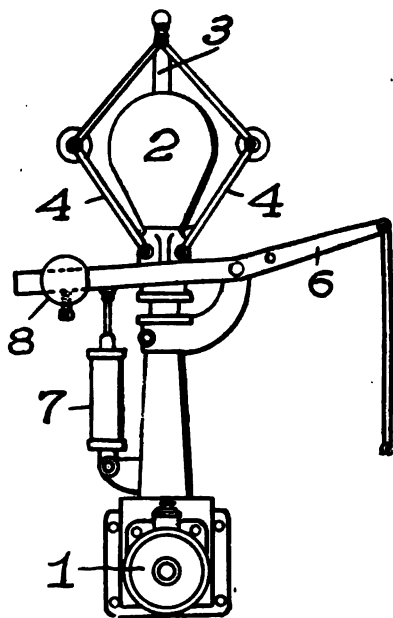
If the belt **breaks** or **slips off** the pulley, the support of the fulcrum is forced back, so as to allow the fulcrum to drop and instantly close the valve.

In Fig. 160 is also shown a sectional view of this governor, giving the different parts of same.

Names of Parts.

- | | |
|-----------------------|--------------------|
| 1. Valve Chamber. | 12. Step Bearing. |
| 2. Valve. | 13. Pulley. |
| 3. Valve Seats (2). | 14. Oil Cup. |
| 4. Frame. | 15. Pulley Shaft. |
| 5. Gears, Mitre (2) | 16. Shaft Bearing. |
| 6. Lever Ball Screw. | 17. Stuffing Box. |
| 7. Arms (2). | 18. Head. |
| 8. Toeplate. | 19. Arm Pins (2). |
| 9. Spindle. | 20. Valve Stem. |
| 10. Short Lever. | 21. Balls (2). |
| 11. Fulcrum and Stud. | 22. Lever Balls. |

The Gardner Spring Governor.—In this type of governor, springs are used instead of a weight for opposing the centrifugal force of the weights. The centrifugal force of the pendulous balls operates against the resistance of this **coiled steel spring**, which is enclosed within a case and pivoted on the speed lever by means of



The Porter Governor.
Fig. 159.

a screw. The amount of the compression of the spring can be changed so as to give a wide range of speed.

Shaft Governors.—As we have seen the **power** of an engine, and hence the work it performs can be regulated either by varying the point of cut off, or the point of compression, or by varying **both** of these points at the same time. One of the easiest methods of doing this is to **shift** the eccentric, so as to vary its **throw** and at the same time its **angle of advance**, thus making the engine a variable cut off automatic engine.

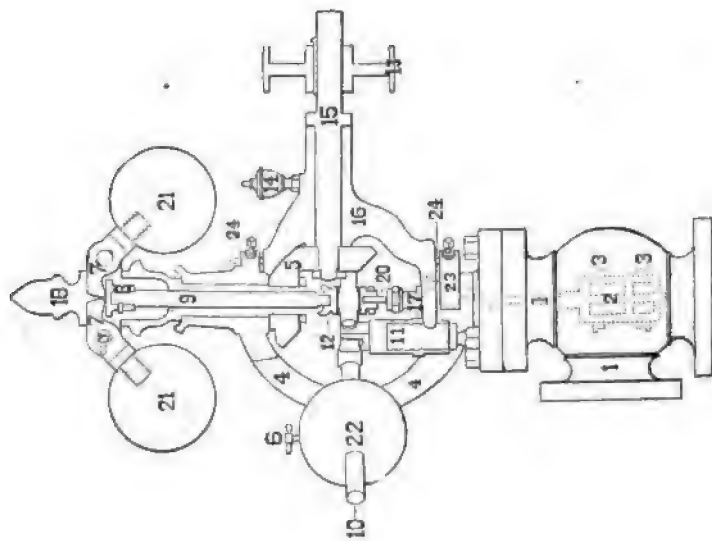
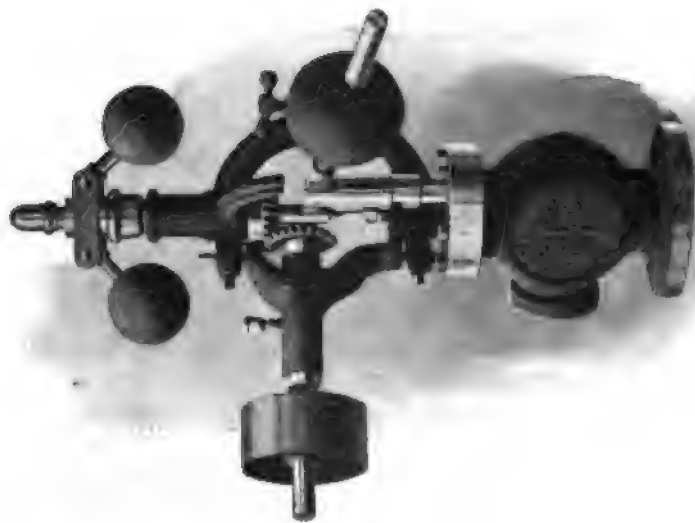
In order to make the cut off **automatic**, it is operated by a governor placed on the main shaft of the engine, and hence is called a **shaft governor**.

Construction.—This governor as usually constructed, consists of two pivoted masses, or weights, arranged symmetrically on opposite sides of the shaft; their tendency to fly **outwards** when the speed increases being resisted by **springs**. The **outward** motion of the weights closes the steam admission valve earlier, that is, **decreases** the steam supply, by making the point of cut off earlier, and the **inward** motion closes the valve later, that is, **increases** the steam supply by making the point of cut off later.

The steam supply is therefore effected by altering the position of the eccentric on the shaft, either by changing the throw of the eccentric, or of the angular advance.

Parts.—The following are the principal parts of an ordinary shaft governor for a high speed engine, the numbers corresponding with the parts shown in Fig. 161:

1. Rim of governor wheel.
2. Fly wheel arm.
3. Main eccentric.



The Gardner Governor, with Sectional View.
Fig. 160.

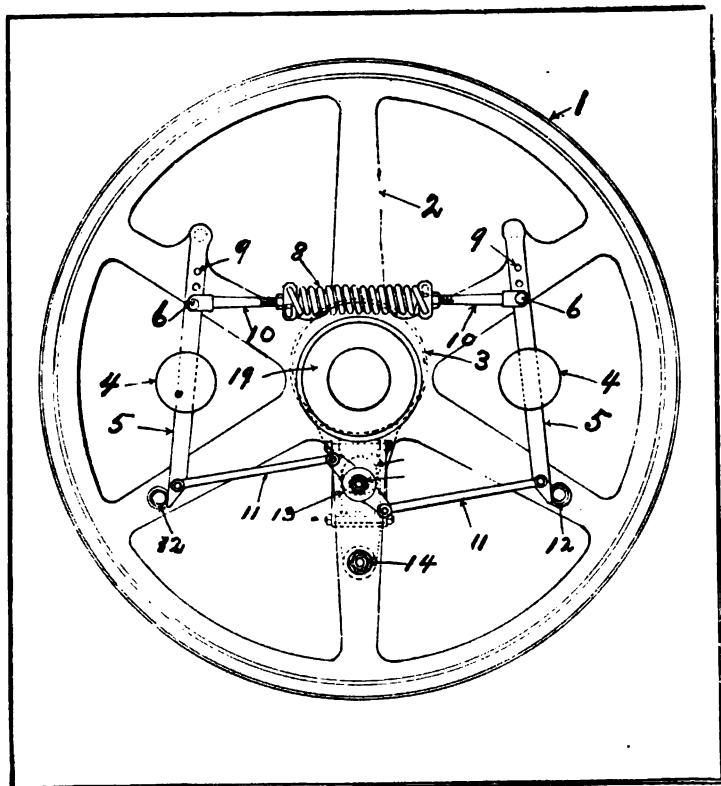
4. Governor weights.
5. Weights lever.
6. Spring link bearing pins.
8. Equalizing spring.
9. Holes for adjusting spring link.
10. Spring links.
11. Weight lever links.
12. Stops.
13. Secondary eccentric crank.
14. Main eccentric bearing pin nut.
19. Hub of governor wheel.

The Inertia Governor.—In the pendulum or throttling governor, we see that the force that regulates the steam pressure is the **difference** between the centrifugal force of the revolving weights, and the **opposing** force which is usually gravity.

In the **shaft** governor, the force that acts to shift the valve or eccentric is the **difference** between the centrifugal force of the revolving parts, and the resistance of the governor **springs**.

In both these forms of governors, the force of **inertia** has to be overcome, as it prevents to a certain extent very close or accurate regulation.

By **inertia** we mean that property of a body by virtue of which it **persists** in its state of rest or of uniform motion in a straight line, unless some force changes that state. It is therefore a **resistance** to any change of motion. As it takes some time and energy to put a body in motion, and when in motion to bring it to a state of rest, this property of inertia therefore acts as a **disturbing** force in the above forms of governors; and to overcome this disturbing force and make it an **assistance** in obtaining a closer regulation, the **inertia governor** was devised.



Parts of a Shaft Governor for High Speed Horizontal Steam Engine.

Fig. 161.

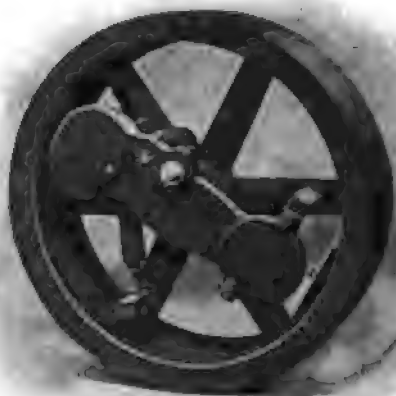
Construction.—This form of governor consists of a wheel which is keyed to the engine shaft the same as an ordinary fly wheel. Pivoted to this wheel is a **bar**, the two ends of which are hollow. A spring is attached to one end of the bar, and the other end of the spring is fastened to the rim of the wheel. One end of this bar is **weighted**, and as the wheel revolves the centrifugal force of the weighted end tends to carry it outwards, this tendency being resisted by the spring.

Should the speed of the engine become **excessive**, the centrifugal force overcomes the opposing force of the spring, and throws out the end of the bar, this motion shifting the eccentric pin, which pin serves the purpose of an eccentric. In this way the throw of the eccentric is **shortened**, and the **angle of advance** increased, thus **decreasing** the speed of the engine by decreasing the amount of steam admitted to the cylinder, as the cut off takes place **earlier** in the stroke.

The inertia of this weighted bar acts as a regulating force, since owing to its weight and length, it offers considerable resistance to any **sudden** change in the angular advance, by allowing the wheel to advance **faster** than the bar. This shifts the eccentric pin nearer the center of the shaft, thereby causing the cut off to take place earlier, and preventing any great increase in speed **before** the centrifugal force can act. On the contrary, should the load on the engine be suddenly **decreased**, in the same way regulation is maintained, for while the speed of the wheel is suddenly checked, the inertia of the bar causes it to move **ahead** of the wheel, and so shift the eccentric as to make the cut off take place **later**.

In Fig. 162 the form of inertia governor used on the Junior engine is shown.

Construction of the Junior Inertia Governor.—This



For Forward Running.



For Backward Running.

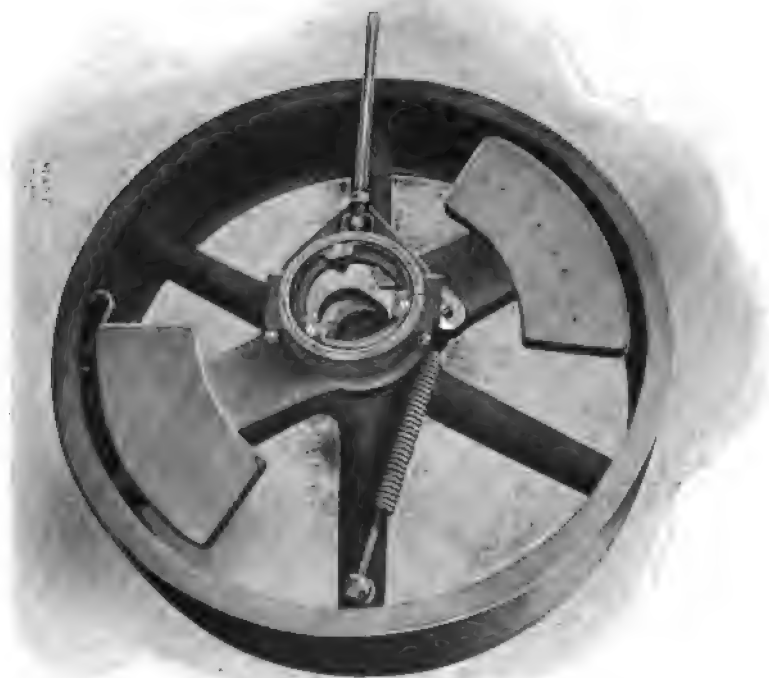
**The Junlor Reversible Inertia Governor.
Fig. 162.**

governor, as shown in Fig. 162, is of the popular "**single weight**" or "**inertia**" type, and is capable of giving that ultra fine regulation generally regarded as such a valuable feature in a steam engine. Aside from its excellent speed regulating qualities, it is particularly attractive on account of its simplicity. The governor weight is a simple casting of the form shown in the engravings on the preceding page. In this weight are screwed three steel pins 1. A small pin carrying a bronze roller, over which is hooked the end of the governor spring. 2. The spindle on which the weight swings. 3. A pin with a spherical head, which constitutes the eccentric.

The fly wheel serves as a carrier for the governor. It has a bronze bushed hole through the hub, a little to one side of the bore for the shaft, in which the spindle on the weight is journaled. This is the only bearing requiring lubrication, which is supplied by a compression grease cup. In suitable bosses in the arms of the wheel are inserted two pins which limit the distance that the weight can swing on its spindle. One of these pins has a hole in it through which the spring tension screw passes.

The standard direction of rotation for Junior engines is such that when facing the nameplate the top of the wheel runs toward the observer, and unless specially ordered to the contrary, governors are set to run in this direction. All Junior engine governors are, however, now so constructed that they can readily be set to run in the **reverse direction**. The operation is exceedingly simple, consisting in simply reversing the weights.

Combination Governor.—The requirements of the modern engine are such that the speed must be maintained practically **constant** through wide variations of



The Brownell Combination Governor.

Fig. 163.

load, and this condition must be maintained whether the change occurs gradually or suddenly. A purely centrifugal governor will handle satisfactorily **gradual** changes in load, but cannot successfully take care of sudden changes; on the other hand a purely inertia governor can care for **sudden** changes, but not gradual changes. To meet all conditions to which the modern engine is subjected, several makes of governors have in combination **both** the centrifugal and inertia elements.

Such a governor as shown in Fig. 163 is used on the Brownell automatic engine.

Construction.—This governor consists essentially of the usual single weighted arm, swinging on a pivot pin. Fastened to this arm is the eccentric that drives the valve. As the weight assumes different positions due to changes in load, the center of the eccentric is brought nearer to or farther from the shaft center, thereby regulating the travel of the valve and the admission of the steam, in proportion to the work required. The entire absence in this governor of the usual complication of links, dash pots, and other interlocking devices, together with its extreme sensitiveness, and the entire absence of any evidence of racing or surging commends it to all practical steam users.

CHAPTER XVII.

VALVE GEARS.

Classification.—The **valve gear**, by which is meant the mechanism used to operate the valve, varies with the different types of engines. For a plain slide valve engine, this mechanism as we have seen, consists of the eccentric, the eccentric rod, rocker arm, valve stem, and the valve itself.

Should the engine be a type of the **reversible engine**, or a **variable cut-off engine**, the valve gear includes in addition to the above, the mechanism by which the motion of the valve is so governed as to change the **rotation** of the engine, or the **amount** of work done in the cylinder.

Fixed Cut-Off Gears.—In this type of gear, the motion of the valve does not vary with the amount of work to be done in the cylinder. Such gear is used on the plain slide valve engine, which has a **fixed** cut off, which cut off cannot be changed without changing the **construction** of the valve itself. When such gear is used, the points of admission, cut off, release and compression cannot be varied.

Variable Cut-Off Gears.—When the amount of work done in the cylinder can be regulated by varying the motion of the valve so as to change the point of cut off while the engine is in operation, the gear then used is designated as a variable cut-off gear. An **automatic cut-off gear**, in which the motion of the gear is controlled automatically by a governor, is called an **automatic variable cut-off gear**.

Reversing Gears.—When it becomes necessary that the direction of the rotation of the engine be constantly

changed, such as in hoisting work, a **reversing** gear must be used.

Types of Valves.—The leading types of valves are; **slide valves**, such as are generally used in slide valve, or variable cut-off engines; **rotary valves**, which are generally used on Corliss engines; and **poppet valves**, used only on slow and medium speed engines.

Of these types of valves, the poppet valves are less frequently used, their use being mostly confined to marine work.

Expansion Valves.—With a plain slide valve driven by a **fixed** eccentric, the range of the cut off is limited. With the "D" slide valve there cannot be an **earlier** cut off than one-half the stroke without interfering with the exhaust.

In order to extend the range of cut off, and at the same time **not** interfere with admission, release and compression, various types of **auxiliary valves**, known as expansion valves, have been designed for use in conjunction with the plain slide valve.

These auxiliary valves are driven by a separate eccentric, they being solely used to govern the **admission** of the steam without in any way interfering with the release and compression. With such an auxiliary valve the lap of the valve, or, the angle of advance may be changed as desired, **without** effecting the other parts in the steam distribution.

Therefore, this auxiliary valve, or riding valve as it is generally called, is alone used to vary the point of cut off.

The Meyer cut-off valve is a well known type of such expansion valve.

The Buckeye Valve Gear.—One of the best known applications of the riding cut-off valve, is the **Buckeye**

valve gear. In this gear the main valve is driven by the usual valve gear of a slide valve engine, making its operation exactly similar to that of an ordinary slide valve with a direct rocker.

The cut-off or auxiliary valve works **inside** of this main valve, which is made either a hollow cylinder or box shape.

In Fig. 185 is shown a sectional view of the cylinder and valve of the Buckeye engine, from which can be seen the operation of this riding cut-off valve.

The main valve has two openings through the top that connect with similar openings in the steam chest. Live steam enters through these passages into the interior of the main valve. This valve has two openings for ports on the **under** side through which the steam is admitted to the opposite ends of the cylinder when these ports come in line with the main steam ports.

As steam is exhausted past the **outside** edges of the main valve, it is therefore an **indirect valve**.

The admission of steam to the cylinder is regulated by the cut-off or riding cut-off valve, opening and closing the two ports in the main valve. This permits the cut off to be varied through a much wider range than possible with a single slide valve.

Disadvantages.—While the disadvantage of the limited range of cut off of the "D" slide valve is partly overcome by the use of these expansion valves, there are many serious objections to their use, all of which are overcome by the use of the Corliss valve gear.

In order to overcome the force required to drive the ordinary slide valve, due to the great pressure of the steam on the back of the valve, which not only materially effects the **action** of the shaft governor, but also of the valve itself from the unavoidable wear from

the frictional resistance of the valve, many forms of so-called **balanced valves** have been produced.

Balanced Valves.—The most successful of these types of valves is the piston valve, heretofore described, which is a light and most perfectly balanced valve. A serious objection to this valve, and which has greatly restricted its use, is the **constant wear** of same. In horizontal engines especially, the weight of the valve invariably wears the lower part of the valve seat, and thus destroys its circular form.

The **flat pressure plate valve** is a type which is also much used. A form of this valve is shown in Fig. 149.

For horizontal engines, the pressure plate valve possesses the advantage over the piston valve in that the wear of the valve which is on the **lower edge**, does not therefore effect the **tightness** of the valve.

The Corliss Valve Gear.—This form of valve gear was invented and first introduced by Geo. H. Corliss in the year 1848. It marked a new era in engine building. He first conceived the governor controlled cut off, and the easy moving valves, with their liberal exhaust ports which take care of both the exhaust and the condensation. It was Mr. Corliss who also first designed the proper engine frame, and made the engine self-contained.

Construction.—In the Corliss gear there is a separate admission valve and a separate exhaust valve for each end of the cylinder, entirely independent of each other. The admission valves are operated by either one or more eccentrics, but they are automatically closed by dash pots or springs, when the piston reaches a designated point of its stroke. This point will vary with the position of the governor, which position will vary

with the speed of the engine, which is controlled by the load on the engine.

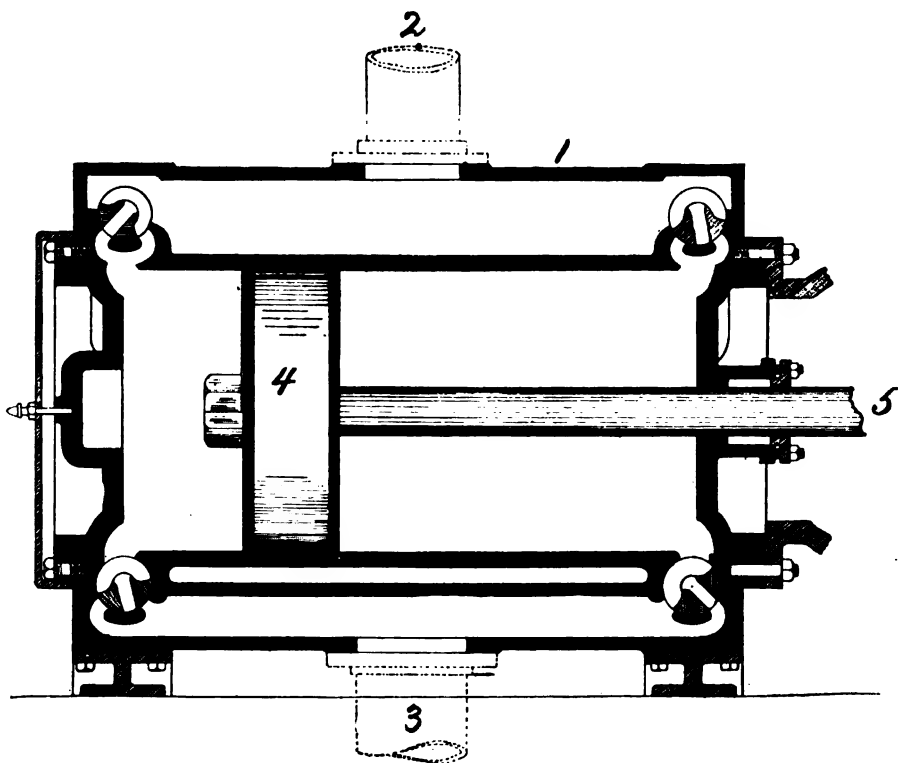
The exhaust valves are opened and closed by the motion of a wrist plate to which these valves are directly connected by rods or cranks. Both the admission and exhaust valves are cylindrical in shape, turning in cylindrical seats which extend across the ends of the cylinder. The wrist plate which operates the exhaust valves alone, receiving its oscillating motion from the eccentric which is fastened to the shaft of the engine.

When the piston reaches the point where the steam should be shut off, the trip gear is held in such a position by the governor that it releases the admission valve, which is snapped shut by the action of the dash pot, or spring. The exhaust valve is made to open by the independent action of the wrist plate which is operated by its eccentric.

The advantage of the Corliss valve gear is the long range of the stroke through which the cut off can be varied, depending only on whether one or more eccentrics are used.

With one eccentric, the cut off ranges from the beginning of the stroke to one-half, at which point the eccentric starts on its return travel. With the use of two eccentrics this range can be extended almost the entire stroke, as the exhaust valves are then operated entirely independent.

In Fig. 164 is shown a sectional view of a cylinder with Corliss valves. As seen from this figure there are four distinct valves, one of which admit steam to the crank end and the other one to the head end of the cylinder. They are in communication with the steam chest and steam inlet pipe. The two lower valves com-



Sectional View of Cylinders showing Corliss Valves.

Fig. 164.

municate with the exhaust chamber and the exhaust pipe. The two upper valves are called the steam valves, and the two lower valves the exhaust valves. Each valve extends across the cylinder, making the length of the valve about equal to the cylinder diameter. As seen from Fig. 164, the steam valves open their ports when their faces move away from the center of the cylinder towards the heads. The valves as shown in the cut are single-ported, that is, they open but **one passage** for the flow of the steam to and from the cylinder, though these valves are often made double-ported.

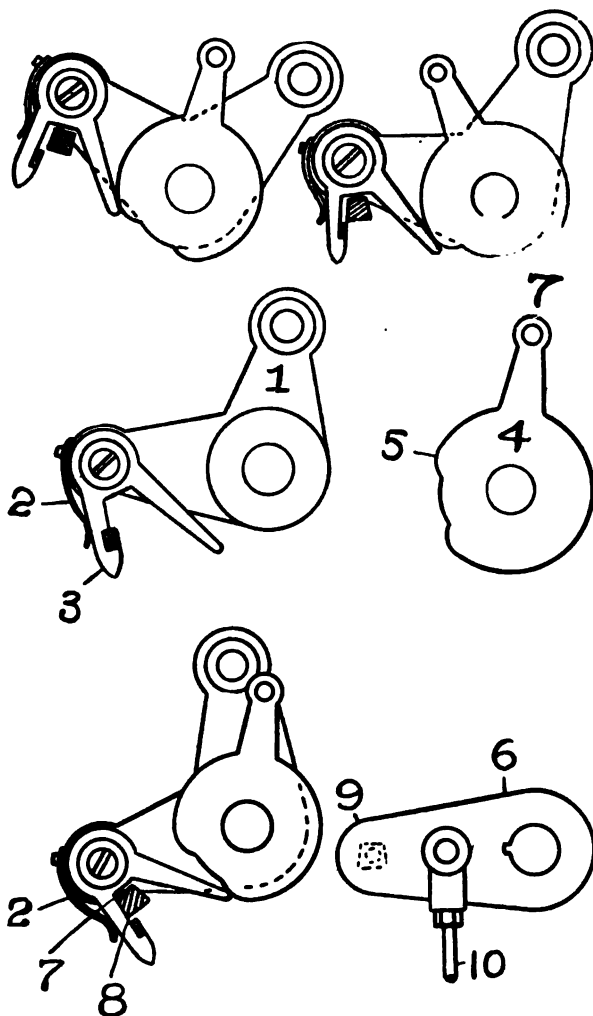
Mechanism for Operating Corliss Valves.—The mechanism or gear employed to open and close the steam valve, embraces the most important features of a Corliss valve gear. The principle on which the operation of all forms of Corliss gear is based is practically the same, differing only in details of construction. The following description will therefore make clear the Corliss valve gear as generally employed, reference being made to diagrams shown in Fig. 165.

On the valve stem is placed a bell crank lever 1. At the end of the horizontal arm of this lever is a hook 3, which works freely on a stud. On the valve stem and placed next to the bell crank lever is a disc 4, which is provided with a projection 5. This disc has an upwardly extending arm 7 to which is connected one end of one of the rods from the governor. At the outer end of the valve stem is placed the valve stem crank 6, which carries at its outer end the block 9, which is engaged by the hook 8, on the end of the bell crank lever. The valve crank stem 6 is connected to the rod 10 from the dash pot. The operation of this mechanism may be understood by referring to the drawing representing the different positions these parts occupy at the begin-

ning of the stroke of the piston. The disc 4, operated by the governor, is in a position to allow the hook 9 to move to its highest position, or that position corresponding to latest cut off, before being tripped by the projection 5.

The hook has engaged the block on the valve stem crank or arm. Now, as the piston moves forward in the stroke, the bell crank lever is turned around on the stem by the rod from the wrist plate. The horizontal arm of the bell crank lever 1 carrying the hook 8, together with the arm on the valve stem, begins to rise and continues to do so until it arrives at the release position. The inner member of the hook follows the periphery of the disc 4, and is held in contact with the knock-off cam by the flat spring 2, which keeps the hook engaged with the block until reaching the projection on the cam. At this point the inner arm of the hook comes in contact with the projection on the disc 4, which forces the former further away from the center of the disc, thereby causing the hook to release the block carried by the arm on valve stem. The arm on the valve stem, being now disengaged from the hook, is rapidly drawn downward by the dash pot and the rod 10, which causes the valve to close the steam port; thus effecting the cut off.

We therefore see that the essential parts of the Corliss valve gear consists of the following, viz.: (1) the steam valves; (2) the exhaust valves; (3) the double arm levers which work loosely on the hubs of the steam bonnets, and are connected to the wrist plates by rods; (4) the wrist plate; (5) the connecting rods, between wrist plate and the double armed levers; (6) the levers which are keyed to the valve stem, and which are also connected by rods to the dash pot; (7) the dash pot



The Mechanism for Operating Corliss Valves.
Fig. 165.

rods; (8) the dash pots; (9) the steam hooks which are carried at the outer ends of the double armed levers, these hooks being provided with hardened steel **catch plates** which engage with the arms, making the arm and the hook work in unison until the steam is cut off. At this point another set of levers or cams (10), connected by the cam rods (11) to the governor, come into play, causing the catch-plates on the hooks to release the valve arms, the outer ends of which are then pulled downward by the dash pot plunger, causing the steam valves to rotate on their axis and thus shut off the steam.

While many attempts have been made to improve the Corliss valve gear, and some have met with a fair degree of success for particular purposes, there have been but few material improvements made upon this form of valve gear.

No other valve admits the steam at so nearly **full boiler pressure**; determines so **accurately** the precise quantity necessary for the stroke; cuts off the supply so **sharply**; works the steam admitted so nearly to its **full expansibility**, nor discharges is so quickly with so little clearance and back pressure as does the Corliss valve.

The distinctive features of the Corliss valve gear has been most clearly and accurately set forth by Professor Robert H. Thurston, as follows:

1. "The use of four valves—two steam and two exhaust—so placed as to reduce 'clearance' to a minimum.
2. "The use of a rotating valve, capable of being cheaply and readily fitted up, of being easily moved, and of being conveniently worked by connections outside the steam spaces.
3. "The use of a 'wrist plate,' caused to oscillate

by a single eccentric, and directly so connected with all four valves that each may be given a rapid opening and closing movement, and be held open and nearly still, at either end of its range, by swinging the line of connection nearly into the line between centers, thus permitting nearly a full opening of port to be maintained during an appreciable interval, and a free and complete steam supply and exhaust.

4. "A beautifully simple and effective method of detaching the steam valve from the driving mechanism, and of insuring its rapid and certain closure at the proper moment, to produce any desired expansion of steam. (He is alluding to the dash pots and their attachments.)

5. "A direct connection of the governor, so as to determine the ratio of expansion, while so adjusting the power of the engine to the work to be done that the variation of speed with changing loads becomes a minimum.

6. "Making this latter adjustment in such a way as to throw the least possible work on the regulating mechanism, and thus to give the governor the greatest possible sensitiveness and accuracy of action.

7. "A form of frame and general design of engine which gives maximum strength and stiffness.

"All these features are combined to form a steam engine essentially different, in general and in detail, from all earlier engines. In operation the engine was found to exhibit a remarkable economy of fuel, and a singularly perfect regulation, and to be far more durable and more economical in cost of repairs, on the average than was generally supposed possible."

Adjustment of Corliss Valves.—The following instructions for making the proper adjustment of the

valves and gear of the Corliss engine are considered sufficiently general to answer for any Corliss valve gear and regulator.

Instructions.—Radial lines showing the opening or working edges or ports and valves will be found on the back bonnet of cylinder, and back end of valves as follows: For the steam ports, a mark on the cylinder coinciding with that edge of the port toward the end of the cylinder, a mark on the back end of valve coinciding with the edge of valve toward end of cylinder. The lap movement of the steam valve is toward that end of the cylinder in which the valve is located. The exhaust valve covers or works over the opening from the valve chamber into the exhaust chest, and the opening edge is that side of the opening toward the center line of the cylinder, and has its coinciding mark upon the cylinder. The mark on back end of exhaust valve shows its opening edge. The wrist plate is located central between the four ports on the front bonnet side of the cylinder, and has marks on the upper side of its hub showing the extremes of its travel and its center of motion.

To set the valves, place and hold the wrist plate on the center mark, or at the center of vibration and by adjusting threads for shortening and lengthening the valve connections, set the exhaust valve at the point of opening, and lap the steam valve from $\frac{1}{8}$ to $\frac{3}{8}$ of an inch, according to size of engine, the less amount for a 10-inch cylinder, and the larger amount for a 30-inch cylinder, and intermediate sizes in proportion. Now connect the wrist plate and eccentric rod and hook, and with the eccentric loose upon the shaft, roll it over and note if the wrist plate vibrates to the marks of extreme travel; adjust at the screw and socket in the eccentric

rod to make it vibrate to the marks. Now place the crank upon either dead center, and roll the eccentric enough more than a quarter of a revolution in advance of the crank, observing at this time in which direction it is desired to run the engine shaft, to show an opening of the steam valve nearest the piston of from $1/32$ to $1/8$ of an inch according to the speed the engine is to run.

This port opening at the dead center is commonly called lead, and is for the purpose of making an elastic cushion for the piston to rebound from or stop against. High-speed engines require more lead than slow-running engines, other things being equal.

Now tighten securely the set screws in the eccentric, and turn the engine shaft over in the direction desired to run it, and note if the other steam valve is set relatively the same, if not, adjust by shortening or lengthening its connection.

At a state of rest the weight of the regulator balls rests upon a pin in the side of the regulator column. To adjust the cam rods have the balls resting upon the stop-motion pin; then move and hold the wrist plate to one extreme of its throw, and adjust the cam rod for the steam valve, now wide open, so as to bring the steel cam on the cam collar in contact with the circular limb of the cut-off hook; move the wrist plate to the other extreme of throw, and adjust the other cam rod in the same manner.

To test the correctness of the cut off, block up the regulator to about its medium height, and, with the eccentric connected to wrist plate, roll the engine shaft very slowly in the direction it is to run; and when the cut-off hook is detached by the cam, stop and measure upon the guide the distance traveled by the cross head;

then continue the revolution of the shaft, and note when the other steam valve is tripped; if cut off is equalized, the distance traveled on the guides will be the same; if not, adjust the cut-off rods until the points of cut off measure alike. The pin in the side of the regulator column, upon which the weight of balls rests, is to be removed when the engine is in motion and up to speed which allows the stop-motion cams to become operative and stop the engine in case of any breakage of the governor bolt, which would allow the engine to run away unless thus guarded against.

To Adjust the Valves of the Reynolds Corliss Engine.—The working edges of the valves and ports are shown by radical lines on the ends of valves and valve chests, at the side of the cylinder opposite the wrist plate. Both steam and exhaust valves indicate lap when the lines on the valves are nearer the center of cylinder than the lines on the chests.

Fig. 182 shows wrist plate central for adjusting valve connections. Three marks on back hub of wrist plate D and one mark on wrist plate stand, which is bolted to the cylinder show how eccentric connection is to be adjusted so that the wrist plate will travel correctly when in motion.

To set valves, place the center mark on wrist plate hub even with mark on wrist plate stand, and then adjust length of valve connections so the steam valves A and exhaust valves B will have lap according to columns in table; the lap being given in parts of an inch opposite the size of cylinder.

Fig. 182 further shows position of wrist plate D when the engine crank is on the center and eccentric set to give steam valves proper lead.

Exhaust valves will be correct if they have been set

as shown in this figure, and will need no further attention. Put crank on center and then move eccentric so that steam valves will have lead according to table; the lead being given in parts of an inch opposite the size of cylinder.

TABLE FOR SETTING VALVES.

Diameter of Cylinder.	Lap of Steam Valves.	Lap of Exhaust Valves.	Lead of Steam Valves.
8	3/16	1/16	1/32
10	3/16	1/16	1/32
12	3/16	1/16	1/32
14	1/4	1/8	1/32
16	1/4	1/8	1/32
18	1/4	1/8	1/32
20	1/4	1/8	1/32
22	5/16	3/16	3/64
24	5/16	3/16	3/64
26	5/16	3/16	3/64
28	5/16	3/16	3/64
30	5/16	3/16	3/64
32	3/8	1/4	1/16
34	3/8	1/4	1/16
36	3/8	1/4	1/16

Types of Corliss Engines.—There is no better way to understand the operation of the Corliss valve gear than a study of the different types of the Corliss engines; and several of the leading types are here given, so that **every part** not only of the valve gear may be fully understood, but also its construction together with that of the engine.

Types.—Most of these different types of the Corliss gear may be divided into two general classes. To

to the first class belong the **crab claw** gear, invented by Geo. H. Corliss, and still used by many Corliss engine builders.

To the second class belong the **half moon** valve gear, as used on the Reynolds-Corliss engine, and which is followed in more recent designs of Corliss engines.

Description.—In the first class, or the old style crab claw gear, the valve opens **towards** the center of the steam cylinder, which **obstructs** the passage of the steam supply, as it forces the steam to pass over and around the valve.

In the second class, or the Reynolds-Corliss valve gear, the steam valve is made to open **away** or **from** the center of the cylinder, thus leaving a clear and direct passage for the steam into the cylinder.

The Corliss valve gear is called a **detachable valve gear** because the valve is opened **positively** at the proper time by the direct action of the working parts of the engine, and continues to open until closed by the detaching or tripping of the hook, which is operated by the action of the cut-off cam. This time, or point, in the stroke at which the tripping takes place is determined by the **position** of the cut-off cams, which are operated and controlled by the governor. This point of cut off is therefore determined by the requirements of the load on the engine.

Construction of Corliss Valve Gear.—The Corliss valve gear and connections are so constructed and arranged that adjustment can be made while the engine is in **motion**, which is not only a great convenience, but facilitates the setting of the valves by the aid of the indicator.

Dash Pots.—Vacuum dash pots are employed on nearly all engines, being fitted with improved regulat-

ing valves which insure a high and uniform vacuum, and render the dash pot absolutely noiseless in operation.

Governors.—The governors employed on Corliss engines are of two types, viz.: the ordinary fly ball or pendulum governor, and the weighted or Porter type of governor.

Stop Motion.—All Corliss governors are provided with a stop motion, which causes the engine to stop immediately upon the failure of the governor itself, or the breaking or slipping of the governor belt off the pulley.

Reversing Valve Gear.—For ordinary stationary work, engines are made to rotate in **one** direction only, there being no necessity to reverse the engine. As we have seen, should it be desired to **reverse** the direction of rotation of the ordinary slide valve engine, the eccentric must be loosened on the shaft and rolled over, so as to occupy a position exactly **opposite** to its former position on the shaft.

Should the engine have a **shaft** governor, the weights or springs must be changed over, so as to act in an opposite direction from what they did in order to reverse the direction of the rotation of the engine.

While these types of engines can be reversed in the manner indicated, the **ratio of expansion** continues uniform, that is, the cut off continues to occur at the **same point** in the stroke.

In some engines the character of the work requires the engine to be frequently and quickly reversed, and also the point of the cut off **altered**, such as locomotives, marine and hoisting engines, where not only the **load** on the engine constantly varies, but also the **direction** in which the engine must be run.

Engines designed for such work must therefore be

provided with certain mechanism that will enable the engineer not only to **reverse** the engine with ease, but also **alter** the ratio of expansion.

Where the work is heavy on the start, as a locomotive pulling a train, suitable means must be provided to give a **late** cut off; and as the work becomes lighter from the train being in motion, the cut off must be made **earlier**, so as to use less steam and allow **more** for its expansion.

With only **one** eccentric, this cannot be done, as the **motion** of the valve cannot be reversed so as to not only change the admission and exhaust ports, but also alter the point of cut off, without **resetting** the entire valve gear.

Now, instead of having only one eccentric, if **two** eccentrics are used, it will permit the motion of the valve to be quickly reversed, and will also allow the point of cut off to be varied, by disconnecting the valve from the first eccentric and connecting it to the second eccentric.

For instance, should the right hand port be opened for admission and the left hand port to the exhaust, then to **reverse** the engine the **travel** of the valve must be reversed, so that the left hand port is open for admission and the right hand port to the exhaust.

In this way the engine can be worked with ease in **either** direction, and the point of cut off varied with the requirements of the load on the engine. There are two principal types of reversing gear, viz.: **link motion**, and **radial gears**.

The Stephenson Link Motion.—One of the earliest and most common arrangements for reversing engines and changing the ratio of expansion, is the Stephenson Link Motion, illustrated in Fig. 183. The two eccen-

trics 1 and 2, whose centers are 3 and 4 respectively, are keyed to the crank shaft of the engine. The two eccentric rods 5 and 6 are connected to the slotted link 11. This link is suspended from the point 13 by the system of levers. The block 14 fits the link, and slides in it when the link is raised or lowered, which is done by moving the lever 7, which raises the link by means of the bell crank lever 8 and the rod 9. The block 14 travels back and forth from 10 to 12, according to the position of the lever 7. The block 14 is directly connected to the valve spindle, which drives the valve 15.

This link motion, therefore, consists of two eccentrics and eccentric rods, and a slotted link.

In this form of link motion, the two eccentrics must be placed on the shaft in such a way that if the valve is operated by one of the eccentrics, the engine will move **forward**, and if by the other eccentric, it will move **backward**. When the block is at the end of the link **nearest** the forward eccentric, the engine will move forward; when the block is at the other end of the link, the engine will then move backward.

As the block is moved nearer an **intermediate** position, the travel of the valve becomes **less**, and consequently the cut off becomes **earlier**. When the block is in a **central** position of the link, the travel of the valve is not enough to uncover the ports, and therefore the engine remains **at rest**.

Where the engine is direct connected, we have seen that the eccentric radius must be 90 per cent plus the angle of advance ahead of the crank. To make the engine run in the opposition direction, it is only necessary to **reverse** the eccentric radius so that it will still **lead** the crank by 90 per cent plus the angle of advance.

This is the principle upon which all reversing valve gear is constructed.

The Gooch Link.—With this gear the link is not raised or lowered, but remains **stationary**. The radius of curvature of the link is made equal to the length of the radius rod. This permits the block to be moved from one extremity of the link to the other, without moving the valve. Therefore, the lead must be **constant** for all points of cut off.

Reverse Valve.—The use of two eccentrics can be dispensed with to reverse the motion of engines by using what is known as a **reverse valve**, such as used to reverse the motion of elevator engines, and which will be described in a later chapter.

Radial Gears.—This is a type of valve gears that perform nearly the same functions as the link motions above described. In these gears the motion imparted to the valve may be varied so that the point of cut off or the direction of rotation, or both, may be readily changed. These valve gears are expensive and difficult to keep in good repair, and are therefore not generally used.

The Joy Valve Gear.—This valve gear is a **radial** valve gear, and is applied to vertical reversing engines. With this gear no eccentric is used, but motion is imparted to the valve by the motion of a connecting rod.

Gridiron Valves.—With this form of valve, a **liberal port opening** can be obtained with a **short range** of travel, thus reducing the wear of the valve and seat, and thereby the power required to operate the valve.

The **disadvantage** in the use of this valve is the resistance to the flow of steam through the narrow passages between the bars, thus causing the steam to be **wire drawn**. This objection can be partly overcome by

the use of a sufficiently **large number** of bars, so that the aggregate area of the openings can be made sufficiently large.

Arrangement of these Valves and Valve Gears.—

The general arrangement of the Gridiron valve and gear can best be understood by describing those of the McIntosh-Semour engine, as shown in Fig. 184.

ST. LOUIS CORLISS ENGINE.

In Fig. 165 is shown a back view of the girder frame type of this engine.

Valve Gear.—The valve gear shown in Fig. 166 is the standard hook releasing type, operated by eccentric on engine shaft; the releasing devices on the steam valves are controlled automatically by action of the governor, and the regulation of the engine is held within 2 per cent under all changes of load within the full capacity of the engine.

The valves are circular, and carefully fitted to the chambers; the valve stems are made from forged steel.

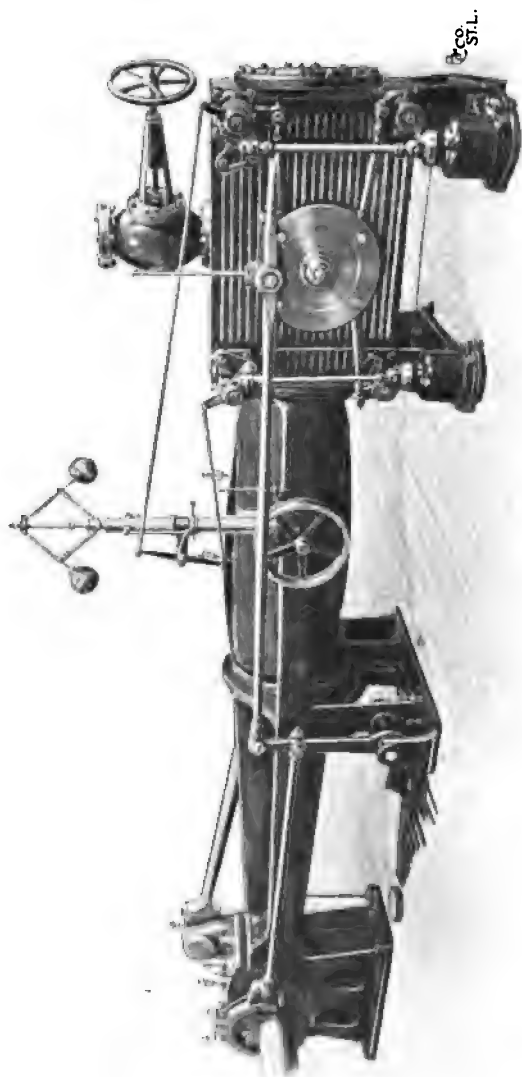
All valve rods are provided with bronze stub ends having adjustable boxes for taking up wear. The valve hooks are also of bronze; all pins are made from forged crucible steel, ground and fitted to gauge.

The wrist plate is circular, with pins located near the circumference giving rapid travel to the valves.

Dash Pots.—The dash pots shown in Figs. 166 and 167 are of the vacuum type, with plungers enclosed, silent and dust proof, self-contained, require no pipe connections, are positive in action under all variations of load or steam pressure.

An air valve is provided for regulating the cushion of the plunger chamber.

Frame or Bed Plate.—The frame as illustrated in



The St. Louis Corliss Engine.

Fig. 166.

Fig. 166 is the standard girder type, with heavy backbone directly in the line of strain, with stiffening ribs at the end of the guides which effectually prevents the guides from springing or opening, whether engine runs under or over.

Cylinder.—The cylinder shown in Fig. 167 is made with heavy walls and strongly ribbed, making it safe to carry high steam pressure.

The cylinder is made from a special clear, close grained iron, very strong; with this iron, after being a short time in use, with good lubrication, a glaze is formed in cylinder, making the wear very slight.

Condensation is almost entirely prevented in the cylinder by providing a dead air space between the exhaust steam passage and the bore of the cylinder; the cylinder is surrounded with mineral wool, and covering the entire cylinder is a cast iron jacket of neat design.

Cross Head.—The cross head shown in Fig. 168 is made with taper adjustable shoes, each lined with best anti-friction metal.

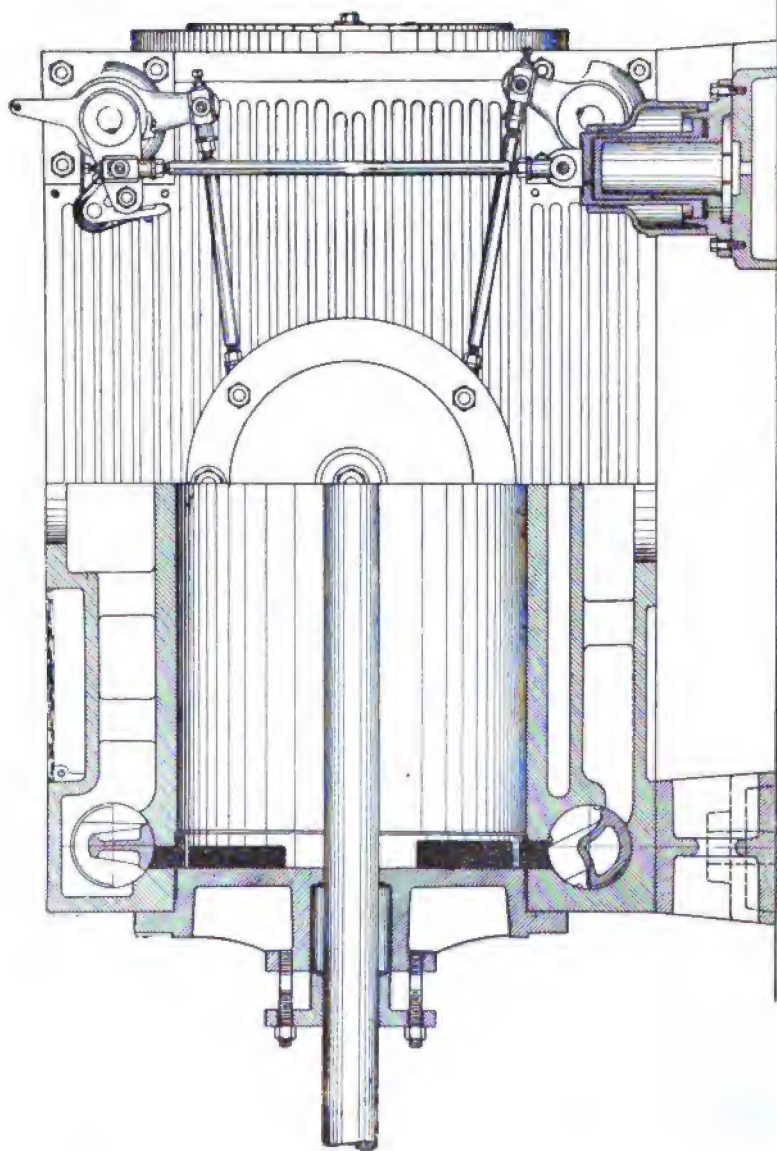
Adjustment is made by means of studs and nuts at the end of the shoes, and the closest adjustment is possible; the shoes can be taken out and re-babbited without removing the cross head.

The shoes are fitted to cross head tightly with tongue and groove.

The cross head pin is located in the center of the cross head, and is ground to a taper fit, held in place by two cap screws.

The cross head is threaded to receive the crucible steel piston rod, which is fitted to the cross head tightly and held from turning by jamb nut.

Main Shaft.—The shafts are made of faggotted hammered iron, turned perfectly true to standard gauges.



St. Louis Corliss Cylinder.
Fig. 167.

Piston.—As the piston and its connections have to receive all the pressure of the steam, being enclosed in the cylinder, where it can only be examined at an expense of time and labor, it is absolutely imperative that it shall not only be extra strong, but safe.

The piston as seen from Fig. 169 is made in three parts, viz.: the head, follower and bull ring. The piston rod is ground to gauge and the piston **shrunk** on, keyed and riveted, making it an utter impossibility to become loose.

The bull ring is provided with sectional packing ring, kept positively steam tight by means of bronze keepers, held in place by non-corroding coil springs.

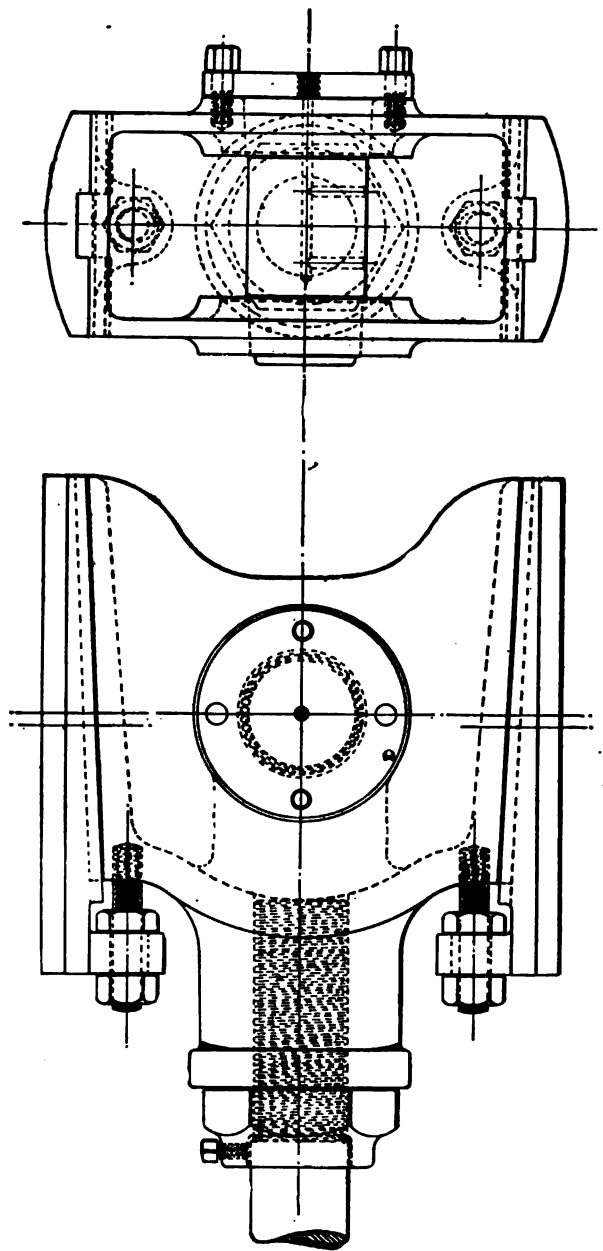
Main Pillow Block.—The pillow block is of heavy design, has a broad bearing at bottom where it rests on foundation, and is held in place by four foundation rods.

The bottom box and two quarter boxes are lined with anti-friction metal, the quarter boxes are adjusted by means of steel wedges, running the full length of the journals, and having adjusting bolts running up through the cap, held in place by jamb nuts.

Crank.—The cranks on all engines above 175 horse power are made of cast steel, having a tensile strength of 60,000 pounds per square inch, equal to the best forged iron.

Connecting Rod.—The connecting rod as shown in Fig. 170 is made solid, from selected forged iron. The ends are afterwards drilled and slotted out to receive the boxes.

Both boxes are made from phosphor bronze, the cross head pin box is adjusted with improved wedge adjustment, while the crank pin box is adjusted by the standard wedge block and bolt; crank pin box is lined with anti-friction metal.



St. Louis Corliss Cross Head.
Fig. 168.

Governor.—The governor is the standard automatic centrifugal ball type, driven by belt from engine shaft.

It is slow speed with heavy balls, giving the closest regulation possible to obtain.

The balls are quick to act whenever there is a change of load on the engine, and the regulation is even and prompt, whether the load is suddenly thrown on or off, or the steam pressure changed.

The governor is fitted with an **automatic safety stop** which shuts down the engine should an accident occur.

It is also provided with an oil dash pot to prevent chasing of engine and a weighted lever to change speed.

Wheels.—The iron used in the manufacture of the wheels is clear selected pig, free from impurities and selected for its strength.

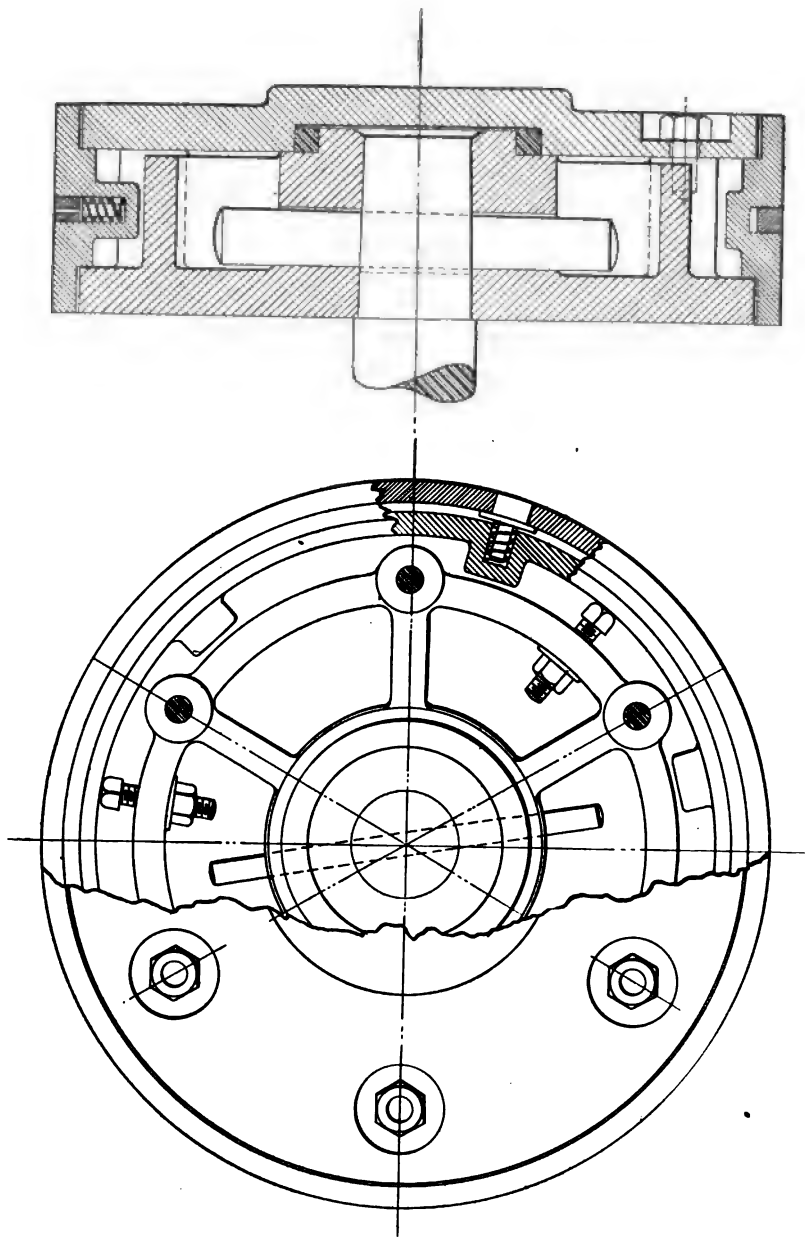
Fly wheels for heavy duty, such as street railways, rolling mills and all direct connected work are made in segments with very heavy I beam arms.

Pins.—All crank and cross head pins are all of generously large dimensions, made of selected, forged crucible steel, ground perfectly true, shrunk into crank and riveted; this plan is considered superior to hydraulic pressing. They are shrunk in at the time crank is shrunk onto the shaft.

THE MURRAY CORLISS ENGINE.

Fig. 171 shows the standard form of a single cylinder Murray Corliss Engine, which is a type of a most economical and efficient engine.

Castings.—The greater part of all engines is composed of cast iron, and on the strength or weakness of such castings, their durability largely depends. This is especially true as to the castings for the cylinders and



St. Louis Corliss Piston.
Fig. 169.

fly wheels, and the builders of this engine have given this most important feature especial attention.

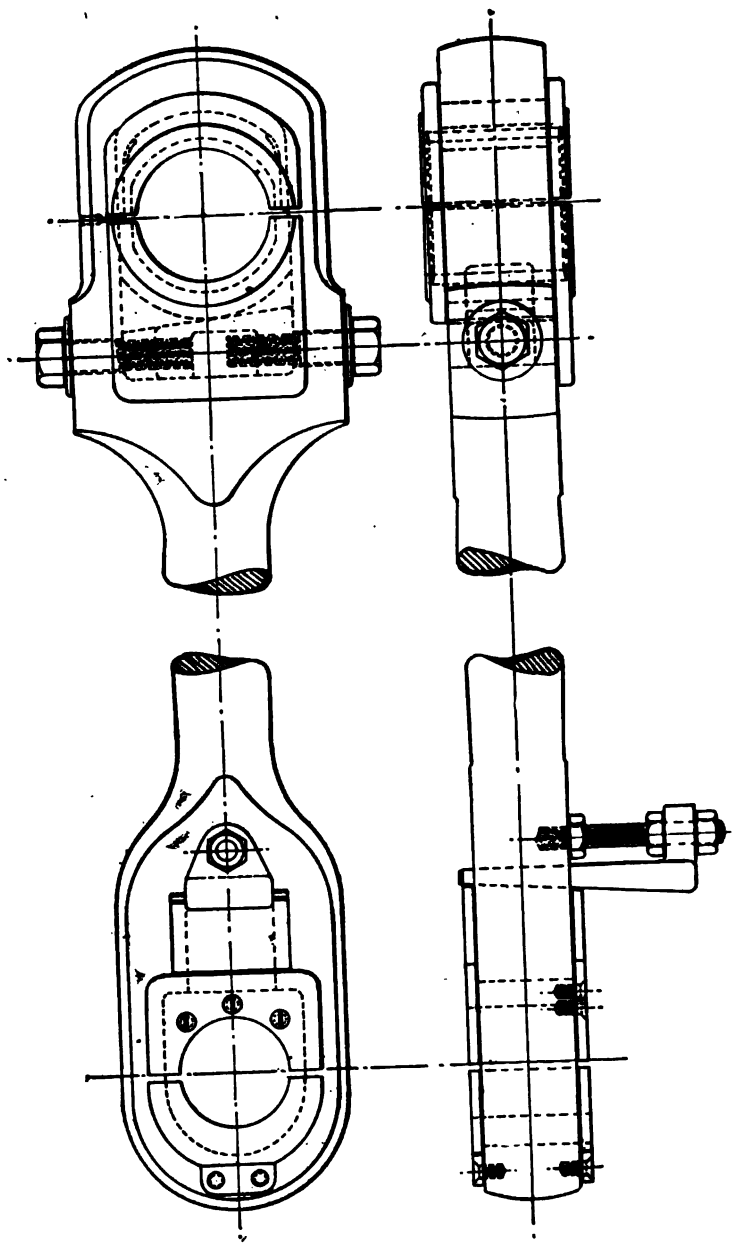
Engine Cylinders.—Fig. 172 shows the cylinder, when partially finished.

1. The exhaust passage is cast **away** from the cylinder, leaving a wide dead air space as the best possible non-conductor, to avoid the loss of heat between cylinder and exhaust chamber by reason of the difference in temperature in steam. Many builders of the old school practice jacketing the lower third of their cylinders with a current of cold wet exhaust steam, which prevents first-class economy.

2. The steam valve of the skeleton type is driven by a T-head valve stem, and therefore perfectly free to find its own seat and adjustment, opening **with** the current of steam rather than **against** it.

3. The exhaust valves have seats directly below their centers, whereby the weight of the valve tends to keep them absolutely and permanently tight. The space in the valve each side of the port, as shown, being made solid, prevents the possibility of loss of steam at each stroke by reason of excessive clearance due to the use of skeleton exhaust valves among the older designs of engines. The cut also shows the heavy solid and substantial cylinder feet which support the cylinders, and which have a projection accurately planed under the dash ment with the working parts of the cylinder. This is a good method of attaching the dash pot, although some very prominent makers place their dash pots on the floor to one side of the cylinder, subject to all the variations due to settling, etc. The cylinders have large air spaces surrounding them underneath the lagging.

In Fig. 173 can be seen the complete cylinder with valve gear, dash pots, disconnecting device, throttle



St. Louis Corliss Connecting Rod.

Fig. 170.



The Murray Corliss Engine.

Fig. 171.

valve; etc., also showing the cylinder feet, which are **extended** to receive the dash pots.

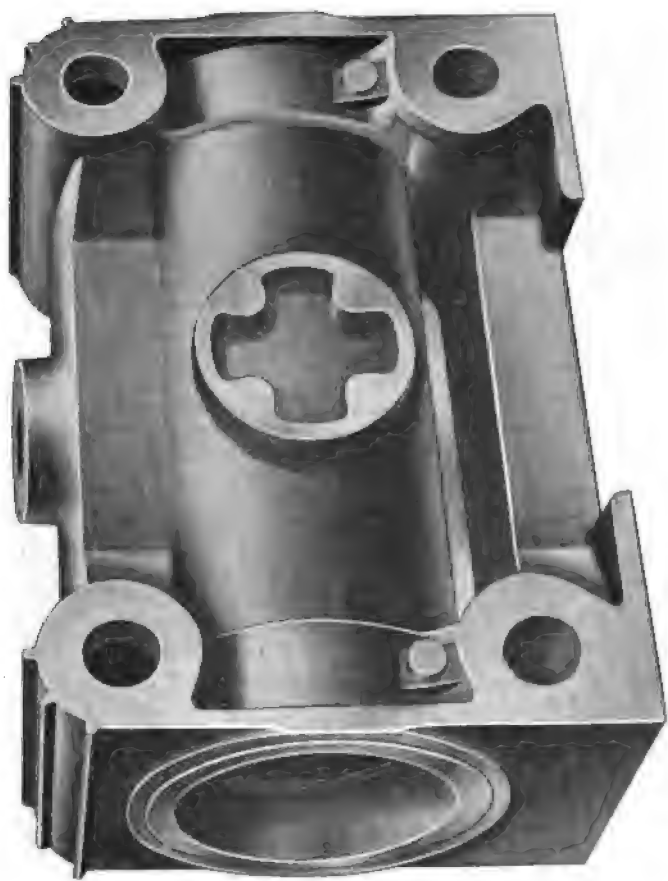
In Fig. 174 is shown the **course** of the steam through the valves. As seen from Fig. 174, the exhaust passages are cast away from the cylinder, leaving a wide dead air space, which is the best of all non-conductors. The course of the live steam is kept away from the cold wet exhaust steam.

Valve Gearing.—Fig. 175 shows the **simplicity** of this releasing gear. The knock-off lever is fitted with **double cams** for use with an automatic safety stop motion, which causes the engine to stop should the governor belt break, or the governor be stopped by accident. The **catch** plates are made of hardened steel, and each has eight wearing edges.

Dash Pots.—This style of dash pot is faced on the bottom, and is bolted to a part of the cylinder foot, which extends to receive it, and which is faced off for it. The adjusting valve is made a part of the dash pot. The plunger has no nuts or screws in the bottom to cause clearance and consequent loss of vacuum, or to get loose and come off or drop into the pot and cause accidents. The lower end of the drop rod is connected to the plunger by a ball and socket joint, with convenient means for taking up the wear; this allows it to be adjusted for length much more conveniently than otherwise, and without the possibility of cramping the rod or plunger.

Piston.—Fig. 176 shows the **solid** piston without follower bolts, which is used with this engine. It is a very simple piston, as it has no follower bolts or studs to come loose or require adjusting. The **packing rings** are made so as to provide for taking up the wear **automatically**, thus remaining tight.

The pistons are pressed on to the rods with hy-



A Partially Finished Corliss Cylinder Casting.
Fig. 172.

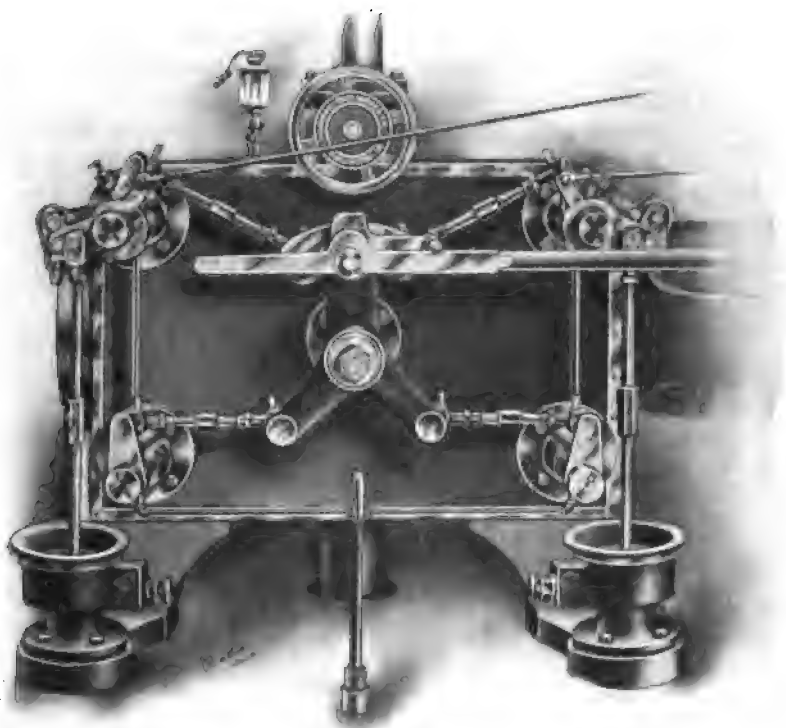
draulic pressure and locked with a special steel nut, which nut is also locked; then the piston and rod are turned up, finished and polished together.

The rings used are sectional or eccentric as the size, speed and working pressure of the engine makes desirable. They are fitted to the pistons by hand and when sectional packing rings are used, the joint and spring clips are made of bronze and the coil springs of spring steel.

Governor.—At the present day when every machine is worked at its maximum speed, and electrical machinery is so frequently driven directly from the prime motor, close regulation is a most important matter, and no one can afford to overlook it or under-rate it. The close regulation of this engine has been obtained by the use of a **high speed governor, making from two to three revolutions to one of the engine**, whereas in the earlier designs of slow speed engines the governor usually made about one revolution per revolution of the engine or less. Consequently this governor is able to act four or five times more quickly than any of the older styles, while it is also more powerful and has less friction and resistance to overcome.

Fig. 177 shows the detail construction of this governor. It will be observed that the center weight of cast iron has a cavity in the top to receive shot or a spring for adjusting the speed even to a fraction of a revolution; also that all the vertical thrust bearings are fitted with hardened steel balls which produce a light running and most sensitive governor.

Special Attachment to Governor.—In order to adjust the speed while the engine is running, a special attachment to governor is used on this engine, consisting of an **adjustable weight**, as shown in the cut. The



**A Complete Corliss Cylinder,
Showing Valve Gear, Dash Pots, Disconnecting Device, Throttle
Valve, Etc., of Murray Corliss Engine.
Fig. 173.**

weight may be moved in or out on the rod and fastened by a screw. Or, if required, the arm and weight may be placed on the other side of the belt crank, thus obtaining quite a wide range of speed adjustment.

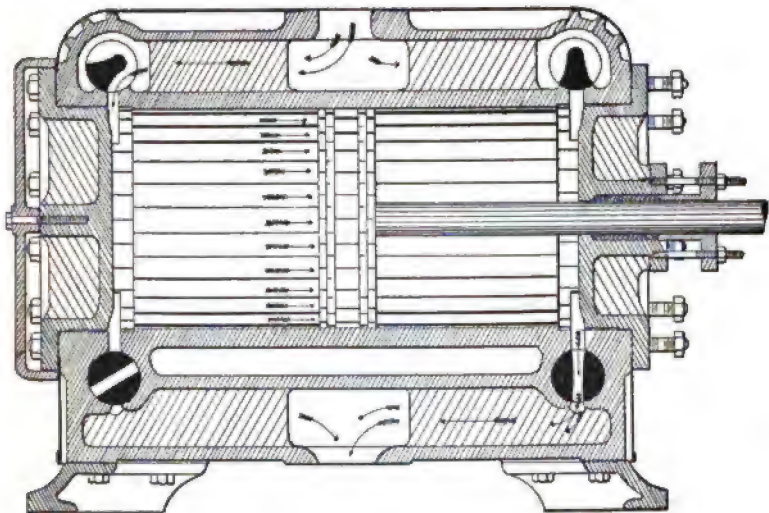
Automatic Engine Stop.—Fig. 178 illustrates the engine stop used on this engine that **automatically** stops the engine by shutting off the supply of steam in case the engine speed either exceeds or falls below the speed desired, also if the governor belt breaks or the governor ceases to revolve from any cause. The valve is placed just on top of the throttle valve and the valve and its gearing are the same as the steam inlet valves of the cylinder except that the valve and port are shorter and wider and that its closure is accomplished by means of a spring or weight in place of a dash pot. The knock-off cam is operated by a rod attached to a bell crank on the governor.

This stop is capable of very delicate adjustment and the valve and valve stem being made of bronze there is no danger of its becoming corroded and sticking. This stop is operated by a separate governor when used on a cross compound engine as shown in the cut.

Economy.—The great **economy** of the Corliss engine in its different forms can be seen from the following table based on actual tests made with the Murray Corliss engines.

HORSE POWER OF STEAM BOILERS WITH DIFFERENT ENGINES.

Size of Boiler.....	42 x 12	48 x 12	48 x 16	66 x 16	72 x 18
Ordinary Engine.....	30	45	60	106	150
Simple Corliss, Non-Condensing.....	41	61	82	144	205
Simple Corliss, Condensing.....	53	80	107	187	267
Compound Corliss, Condensing.....	68	100	135	237	340



**Vertical Section Through Corliss Cylinder, Showing Course of the
Steam.**

Fig. 174.

THE HAMILTON CORLISS ENGINE.

In Fig. 179 is shown this make of a **high speed** Corliss engine.

THE HARRISBURG FOUR-VALVE ENGINE.

In Fig. 180 is shown this four-valve engine, which is especially adapted for high speed work, such as electric lighting or power.

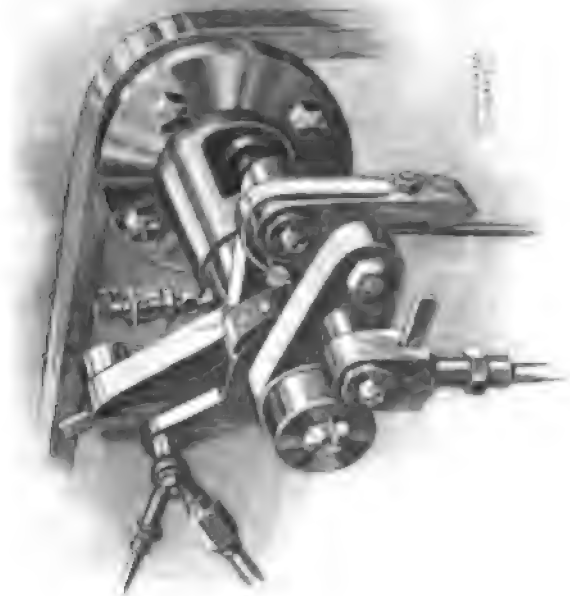
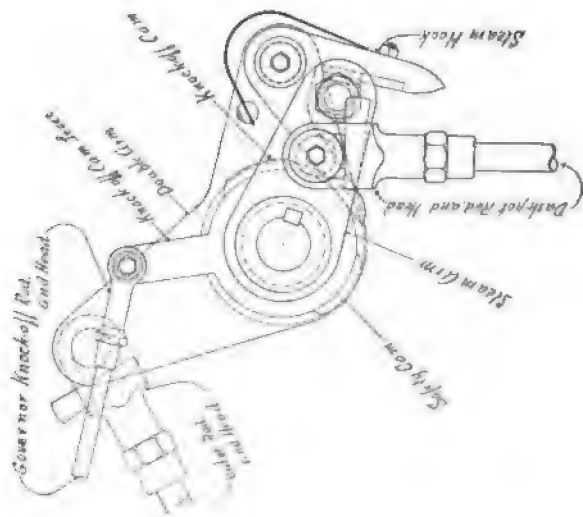
THE PORTER-ALLEN HIGH SPEED ENGINE.

In Fig. 181 is shown this well known engine, which embodies the inventions of the eminent engineers, Mr. Chas. T. Porter and Mr. John F. Allen. It was the first high speed engine constructed for heavy work at high rotative speed, having a high degree of economy.

Valve Gear.—The valve gear is of a distinctive type, the principal feature of which is a **link**, actuated by a single eccentric, from which **separate** and **independent** movements are given to the admission and exhaust valves.

THE McINTOSH-SEYMOUR ENGINE.

Construction.—The flat Gridiron valve of this engine, as shown in Fig. 184, is clearly seen. These valves are unbalanced, and the port edges are so arranged so as to be wide open without forming shoulders. The steam valves are free to lift, which gives additional security against damage from water in the cylinder. The valve seats are separate from the cylinder and are fitted with scraped joints, so as to be steam tight without packing. Both valves and seats are scraped to surface plates, and have their port edges, as well as oil and wipe-over grooves, accurately machined. These valves require much less waste or clearance space usual with Corliss valves, where the cylinder dimensions and port areas are the same.

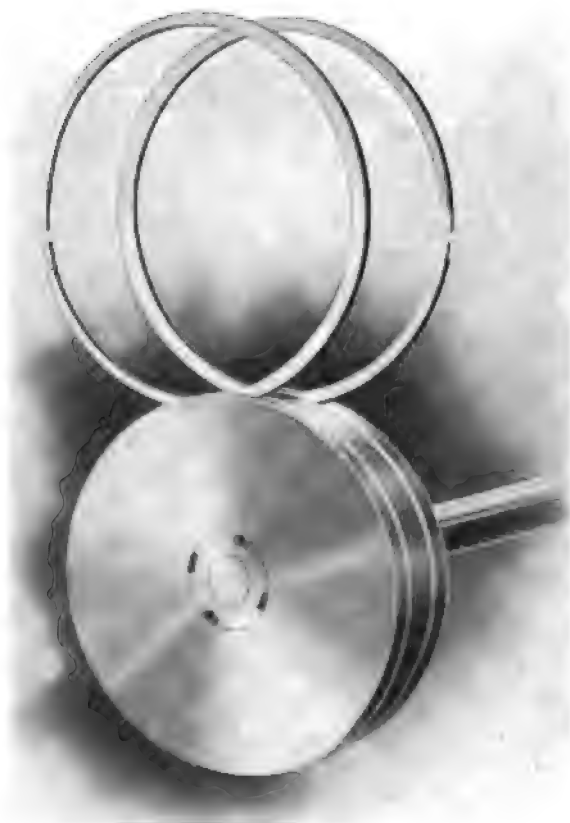


The Murray Corliss Valve Gearing.

Fig. 175.

In the valve gear, as shown in Fig. 184, links, which are used to transmit motion to the valves, are actuated by swinging rockers in such a way as to distort the motion as received from the eccentric, hastening the movement of the valve when near one end of its stroke, and at the other end causing a pause in its motion, so that while a rapid opening and closing of the port is secured, the valve remains practically still while closed. This feature and the large number of ports in the valve reduce the stroke necessary to give full port opening to from one-half inch up to one and one-half inches for cylinders of the largest size, and, since the movement of the valve takes place chiefly when it is open and relieved of the pressure of the steam, the wear, and also the power required to operate the valves, is reduced to a very small amount, and lubrication is made easy.

The valve gear is simply an arrangement of links, rock shafts and slides for transmitting the motion of the eccentrics to the valves. Its construction throughout is unusual, as compared with valve gears containing dash pots or tripping devices, in that provisions are made for securing at all times smooth and quiet running. Every part subject to wear is made adjustable, and since the movement of the parts is small and the bearing surfaces are large, adjustment to insure quiet operation is necessary only at infrequent intervals. The rock shafts, pins and links are made of open-hearth steel. Connecting links are fitted with bronze heads having quick taper-key adjustment, and the rock-shaft bearings are babbitted and are easily adjusted. The valve gear is arranged so as to equalize the cut offs at both ends of the cylinder at all loads. The eccentric operating the cut-off valves is controlled by the governor. The main valves are driven by a fixed eccentric



A Solid Piston with Packing Rings.

Fig. 176.

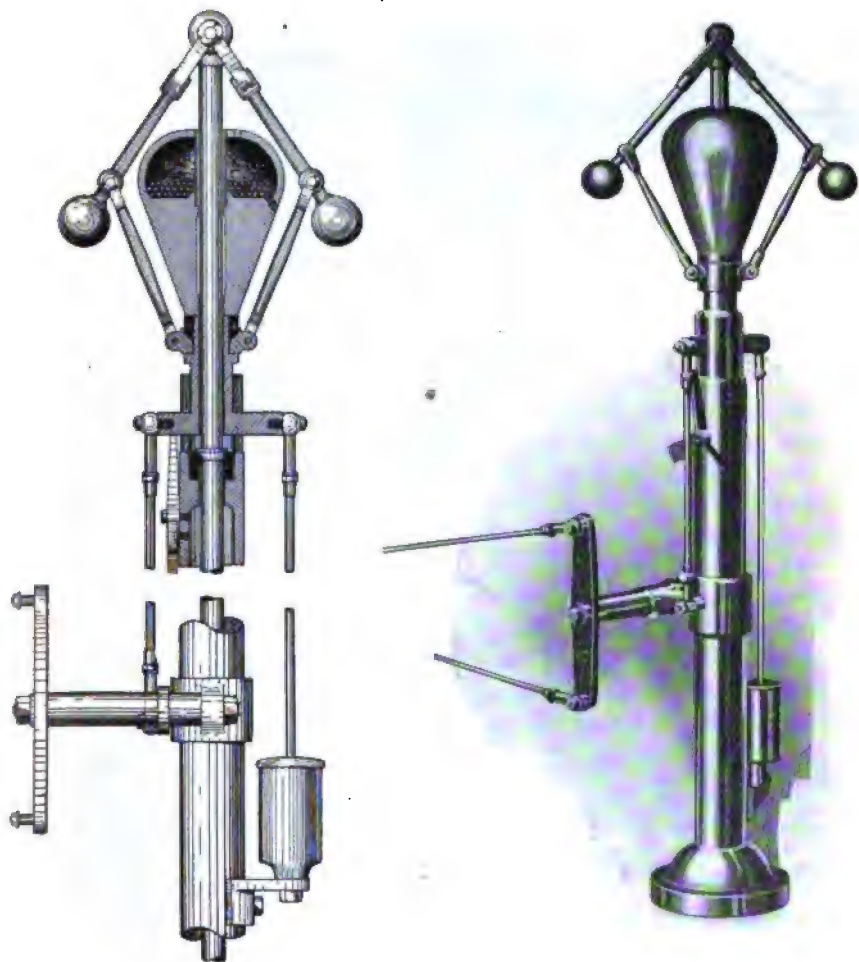
controlling the admission of the steam and the opening and closing of the exhaust. One valuable feature of this arrangement is its perfect flexibility. Any one of the four operations of admission, cut off, release or compression, and for either end of the cylinder, can be varied independently of the others by adjustment of the gear. On multi-cylinder engines the governor usually controls the cut off on all the cylinders so that the work is divided equally among them and the drop in temperature of steam kept the same in each; hence the engine works as economically as possible under variable loads without the necessity of any hand adjustment.

THE BUCKEYE ENGINE.

The distinguished features of this engine are the **Riding cut-off valve** and the **governor**.

A sectional view of this valve is shown in Fig. 185, which represents a section of a single engine cylinder and valves. Both the main and cut-off valves are cylindrical, the cut-off valve working within the main. Both valves are perfectly balanced and both have an absolutely uniform travel, which overcomes all tendency to uneven wearing of surfaces and as this travel extends beyond the seat surfaces there is no shouldering.

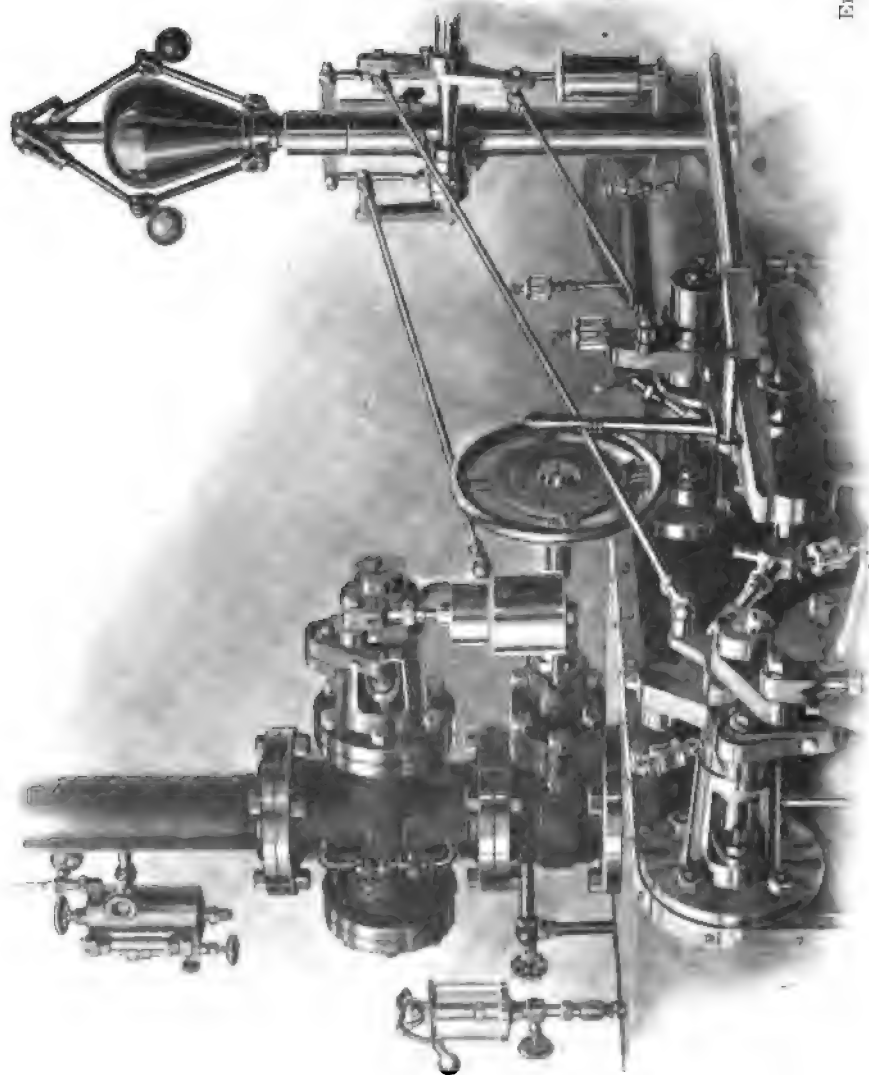
It contains the only perfectly balanced cylindrical valve in existence with which a riding cut-off valve can be used. All attempts to use unbalanced valves with riding cut-offs for automatic cut-off regulation have failed from the excessive friction and wear involved, for, as should be understood, the admission of the full boiler pressure to the valve constantly is one of the conditions necessary to perfect regulation of cut-off, and the realization of its benefits in the way of steam economy. In the common "throttling" engine, the valve is protected



Governor on Murray Corliss Engine.

Fig. 177.

Automatic
Engine Stop.
Fig. 178.

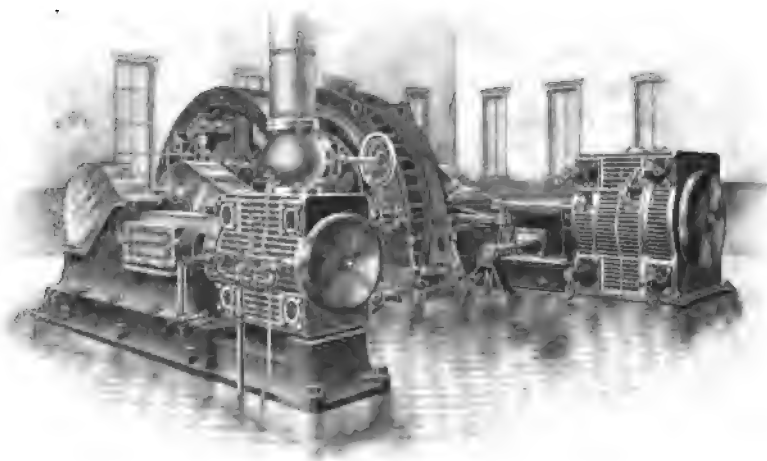


from the full boiler pressure by the throttling process of regulation; hence, unbalanced valves can be used on them; but when the riding cut-off is the regulating agent, it enjoys no such protection, and if such a pressure is carried as good economy requires, and which may be easily sustained by other parts of the engine, its early destruction is inevitable.

Buckeye Governor.—In Fig. 186 is shown the governor used on this engine, which is the **pioneer shaft regulator**, from the fact that it was the first successful regulator of its type ever produced.

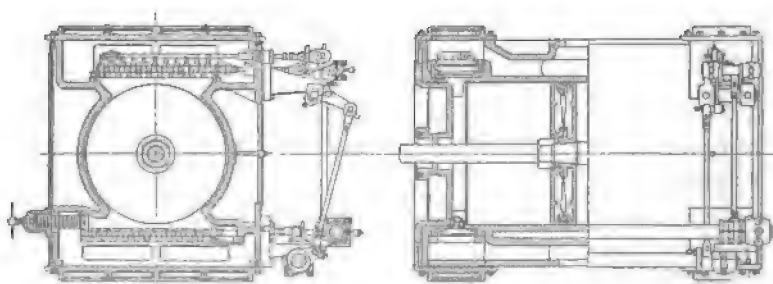
Safety.—The governor being secured directly on the engine shaft, and driving its valve as **positively** as the main valve, through an eccentric rod, rock shaft, and valve stem, the danger of the engine becoming detached from it and destroying itself and the lives of those in its vicinity, is entirely obviated. Such danger always impends when connecting mechanism between the engine and its regulator (particularly belting) is used. Instances of disaster to the engine and driven machinery, involving in many cases the loss of life, from the accidental detachment of the governor from the engine, are numerous.

Regulation.—The construction of the governor permits such an adjustment of the centrifugal and centripetal forces to each other as will give in each case as close regulation as the nature of the conditions which affect the action of the governor will permit. If the machinery driven contains in itself considerable momentum to assist that of the fly wheel, and is not subject to sudden and extreme changes of resistance, the conditions are favorable to close regulation, and in such cases the variation of speed can, if desirable, be confined within 1 per cent, or less; but when the load is desti-



The Harrisburg Four-Valve Engine.

Fig. 180.



Gridiron Valve and Valve Gear of the McIntosh-Seymour Engine.

Fig. 184.

SPECIFICATIONS FOR CORLISS ENGINE.

We propose to furnish you in accordance with the following specifications:

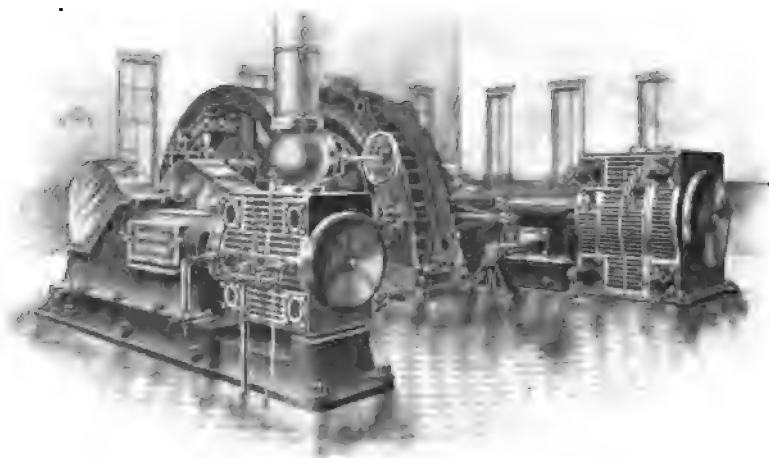
Type of Engine.—Engine to be of our type; and to run at revolutions per minute with pounds steam pressure hand.

Cylinder Dimensions.—Diameter of H. P. cylinder inches. Diameter of L. P. cylinder inches. Length of stroke inches.

Material and Finish.—Shaft and connecting rods to be of best quality hammered wrought iron, free from flaws or other imperfections, and to be nicely finished. Pistons and eccentric rods, crank and crosshead pins, also wrists of valve gear to be of best quality forged steel. Great care will be exercised in making the castings of best quality as regards strength, wearing qualities and smoothness. All castings subject to wear will be poured from special heats of charcoal iron mixture. All parts will be made to gauge and interchangeable. Workmanship and finish will be first class in every particular. Engine to be primed, rubbed down, painted and varnished.

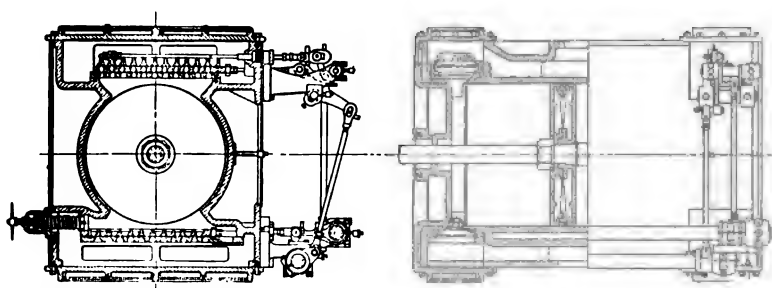
Guarantee.—We guarantee the workmanship and material in the engine to be first class, and we will furnish without charge a duplicate of any part that may prove defective in material or workmanship, provided an inspection proves the claim, within one year after engine is started. We guarantee the engine to run smoothly and in a proper manner, without undue heating or vibration.

Conditions of Operation (300 I. H. P. Noncondensing).—The engine is to run noncondensing at 200 revolutions per minute. Steam pressure 125 pounds above the atmosphere. Back pressure 15 pounds absolute. The



The Harrisburg Four-Valve Engine.

Fig. 180.



Gridiron Valve and Valve Gear of the McIntosh-Seymour Engine.

Fig. 184.

SPECIFICATIONS FOR CORLISS ENGINE.

We propose to furnish you in accordance with the following specifications:

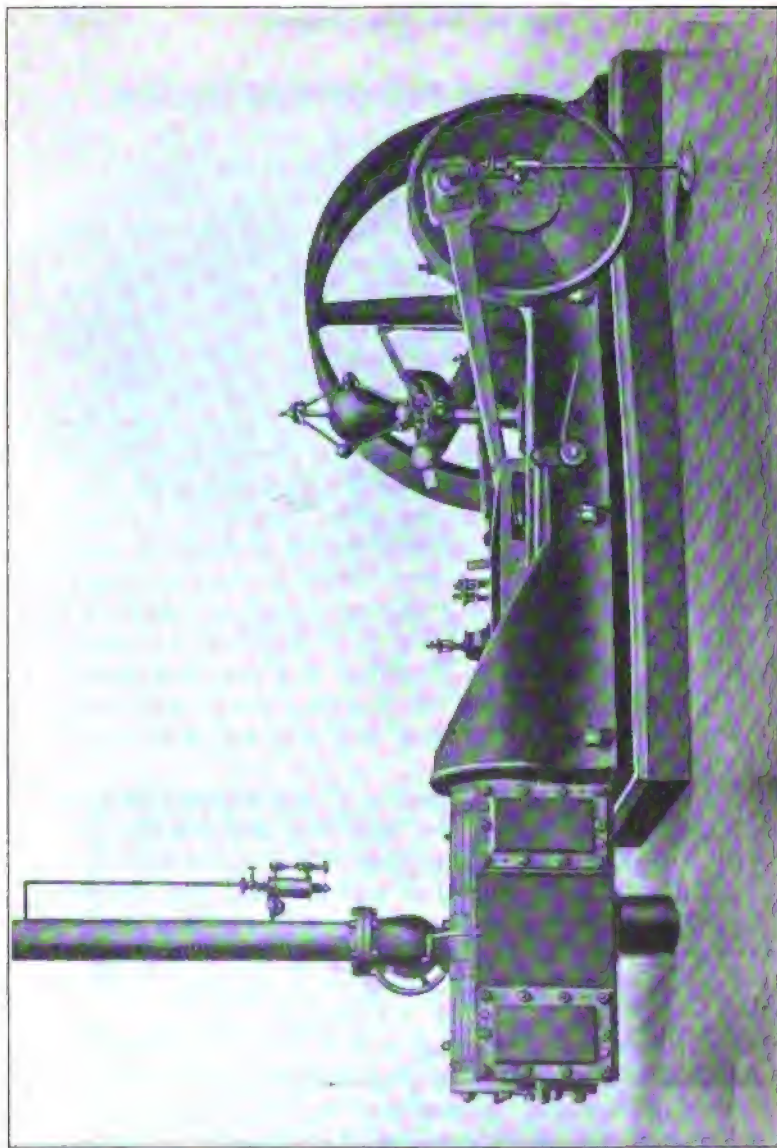
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Cylinder Dimensions.—Diameter of H. P. cylinder inches. Diameter of L. P. cylinder inches. Length of stroke inches.

Material and Finish.—Shaft and connecting rods to be of best quality hammered wrought iron, free from flaws or other imperfections, and to be nicely finished. Pistons and eccentric rods, crank and crosshead pins, also wrists of valve gear to be of best quality forged steel. Great care will be exercised in making the castings of best quality as regards strength, wearing qualities and smoothness. All castings subject to wear will be poured from special heats of charcoal iron mixture. All parts will be made to gauge and interchangeable. Workmanship and finish will be first class in every particular. Engine to be primed, rubbed down, painted and varnished.

Guarantee.—We guarantee the workmanship and material in the engine to be first class, and we will furnish without charge a duplicate of any part that may prove defective in material or workmanship, provided an inspection proves the claim, within one year after engine is started. We guarantee the engine to run smoothly and in a proper manner, without undue heating or vibration.

Conditions of Operation (300 I. H. P. Noncondensing).—The engine is to run noncondensing at 200 revolutions per minute. Steam pressure 125 pounds above the atmosphere. Back pressure 15 pounds absolute. The



The Porter-Allen High Speed Engine.
Fig. 181.

maximum load for which engine is intended equals 400 I. H. P. The engine is to operate at highest efficiency with load equal 300 I. H. P. The average load will equal 175-200 I. H. P.

Speed Regulations.—The speed regulation shall be within 1.5 per cent above or below normal.

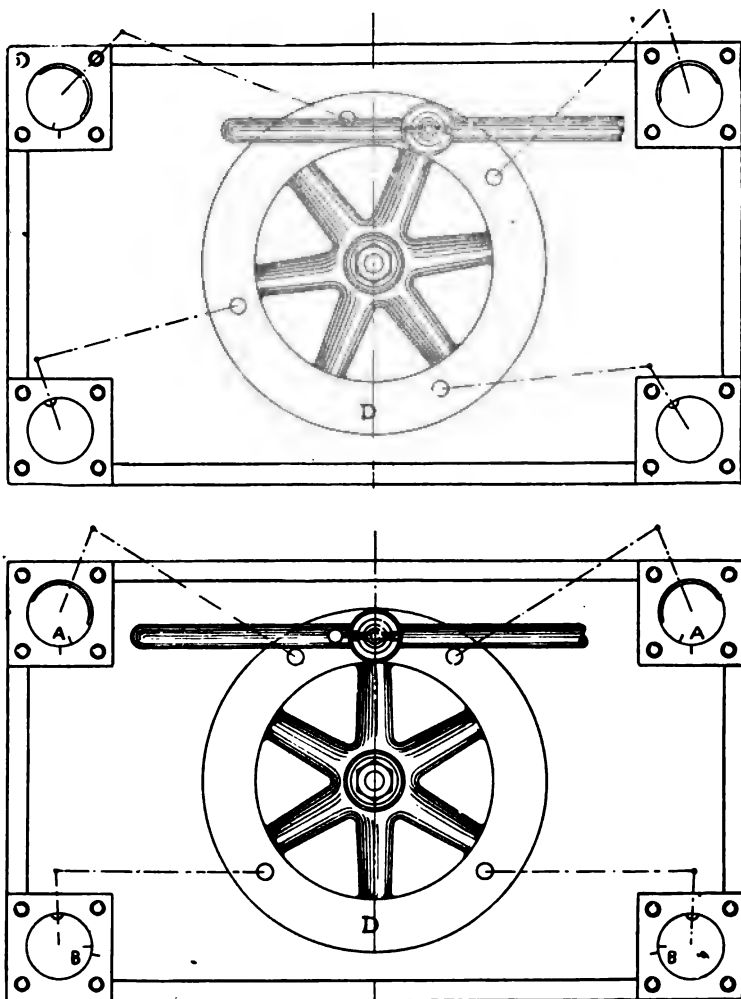
Piston Speed.—The piston speed regulation shall be not less than 560 feet per minute, nor more than 600 feet.

Clearance.—The clearance shall not exceed 8 per cent.

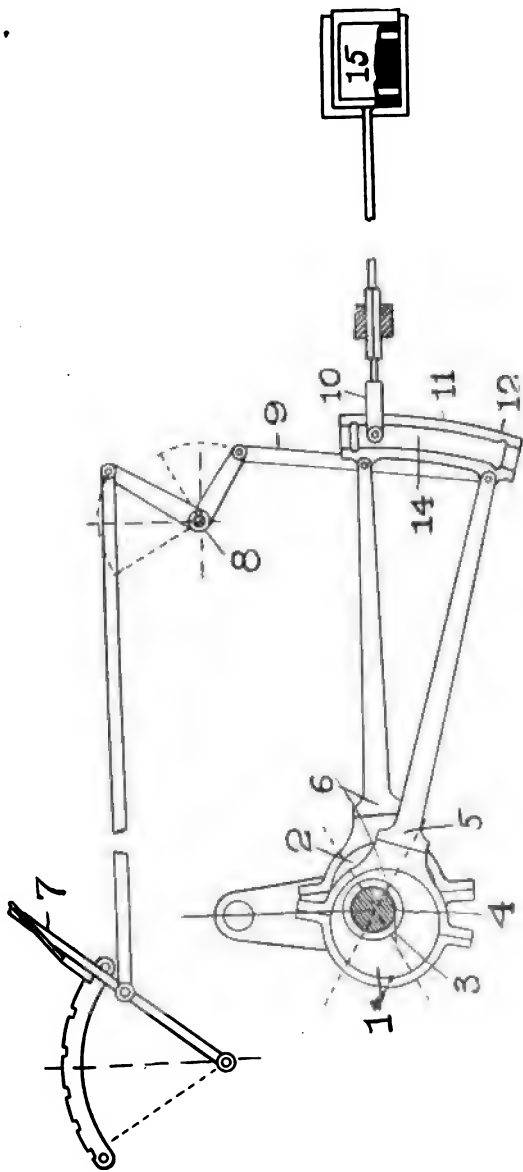
Erection.—We will furnish the time of one man days to superintend the erection and start engine, his traveling expense and board to be paid by you. We consider as legitimate traveling expenses, railroad fare and transfer charges, sleeping cars (when traveling at night), meals enroute, excess baggage or other transportation charges on tools or materials. You are also to prepare the foundations in accordance with our plans, do all piping, packing, belting, mason and carpenter work, and furnish all laboring help and requirements to facilitate erection. When delays are caused to our man by material or labor not furnished by us, you agree to pay his time at \$5.00 per day and expenses while so delayed; our responsibility being limited to the engine proper and the accuracy of our plans.

Price.—We propose to furnish the foregoing machinery as specified for the sum of dollars (\$).

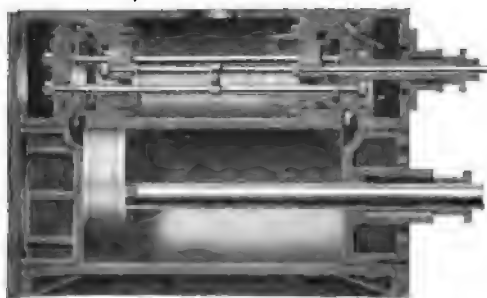
Terms of Payment.—Payment to be made as follows: when engine is ready for shipment; balance days after shipment.



Adjustment of Corliss Valve Gear.
Fig. 182.

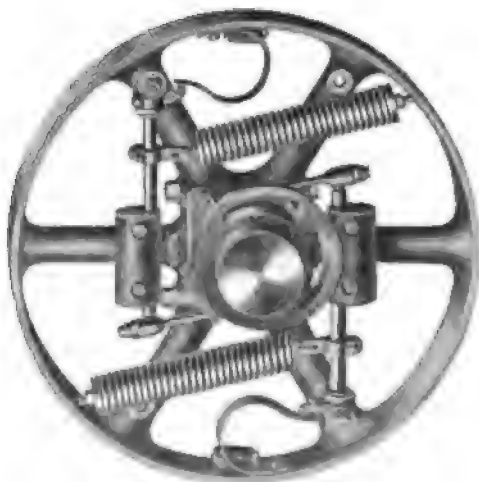


The Stephenson Link Motion.
Fig. 183.



Section of Buckeye Engine Cylinder and Valve, Showing Riding Cut Off.

Fig. 185.



The Buckeye Engine Governor.

Fig. 186.

CHAPTER XVIII.

CONDENSERS.

Theory of the Condenser.—When a vessel is filled with steam at atmospheric pressure, and the steam is **condensed** by bringing it in contact with cold water, the steam will again appear in a liquid state, but will occupy only $1/1669$ part of its original volume. The heat of the steam passes into the cold water, raising its temperature in proportion to the amount the temperature of the steam was **lowered**.

If we take a cylinder fitted with a piston, and connect its closed end to a vessel filled with steam, upon condensing the steam in the vessel, the atmospheric pressure on the piston will force it down, there being upon it a pressure of about 15 pounds to the square inch, which is the pressure of the atmosphere on the one side of the piston; and there will be a partial vacuum on the other side of the piston. This vacuum is created by decreasing the volume of the steam which formerly filled it, to a volume 1669 times as small.

The first steam engines constructed were condensing or atmospheric engines, the steam being condensed in the **cylinder** itself, and the weight of the atmosphere furnishing the power to force the cylinder down, the live steam being used only to force it up against the weight of the atmosphere.

The waste of steam, and the other great disadvantages of condensing the steam in the cylinder, are obvious.

In the year 1765 James Watt first condensed the steam in a **separate** chamber from the engine cylinder, instead of using a spray of water injected into the cylinder itself after the piston had completed its stroke.

This was the **first step** in the direction of increasing the efficiency of the engines then in use, and from which beginning has been developed the multiple expansion condensing engines.

Jet Condensers.—Where a sufficient quantity of water is available suitable for **boiler feeding** purposes, the **jet condenser**, being the simplest and easiest method to operate, is preferable for condensing purposes.

In Fig. 187 is shown a complete installation of a jet condenser.

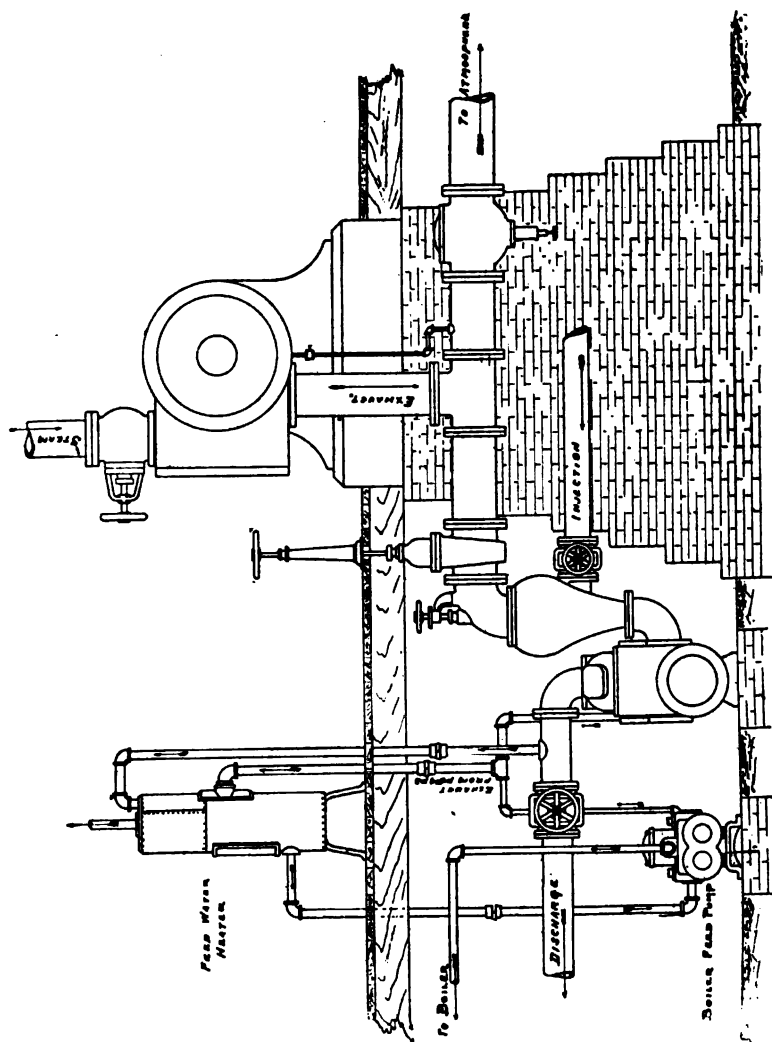
Directions for Installation of Jet Condenser.—The injection opening should not be more than 20 feet above the surface of water supply.

The injection or suction pipe must be full size of the opening given on the condenser. If this pipe is long, say over 80 feet, a larger pipe must be employed; for increased distances its diameter should be further increased. The condenser can be located on either side of the air pump, so that the injection pipe may lead to the condenser, in the most direct way, and with as few bends as possible.

Provide the injection pipe with a strainer to arrest foreign matter; also, provide it with an injection valve, placed within easy reach of the engineer to regulate the supply.

In all cases, where it is possible to do so, an exhaust relief valve should be placed in steam pipe from the engine to condenser so as to relieve to the atmosphere. Conditions may arise wherein the safety device provided with the condenser may be of no service, through no fault of the condensing apparatus, however; so that the installation of the relief valve is a wise precaution.

The plan of installation given is one that is the most practicable in the greatest number of cases, as it



A Complete Installation of a Jet Condenser.
 Fig. 187.

admits of placing the condenser nearer the level of supply of injection water. Condenser can, however, be placed on the same floor with the engine, the injection water level and other local conditions permitting.

Ample and convenient hand-hole plates should be provided, so that the operator may inspect condenser, and remove all extraneous matter that may be lodged therein by the injection water.

It is absolutely necessary that the steam pipe, injection water pipe, all valves and auxiliary pipes should be **absolutely** tight, as the efficiency of the condenser depends on a high vacuum and in order to obtain this every joint must be tight.

Instructions to Engineer.—A good vacuum cannot be made unless you have all piping, valves, joints, etc., tight, or if your engine takes in air at the stuffing-box of valve stem or piston rod.

Never start your engine without running the air pump, unless you can exhaust direct to the atmosphere.

Before starting the air pump, drain its steam cylinder of condensation by means of its drain valves; open the exhaust relief valve.

Start the air pump and then open the valve on injection or suction pipe just enough to admit the required amount of water for condensing when engine is running under full load.

Start your engine and close the exhaust relief valve.

The slight pounding is a good indication; it means that your water piston is slightly ahead of the water as it should be. Run at a piston speed to just keep in advance.

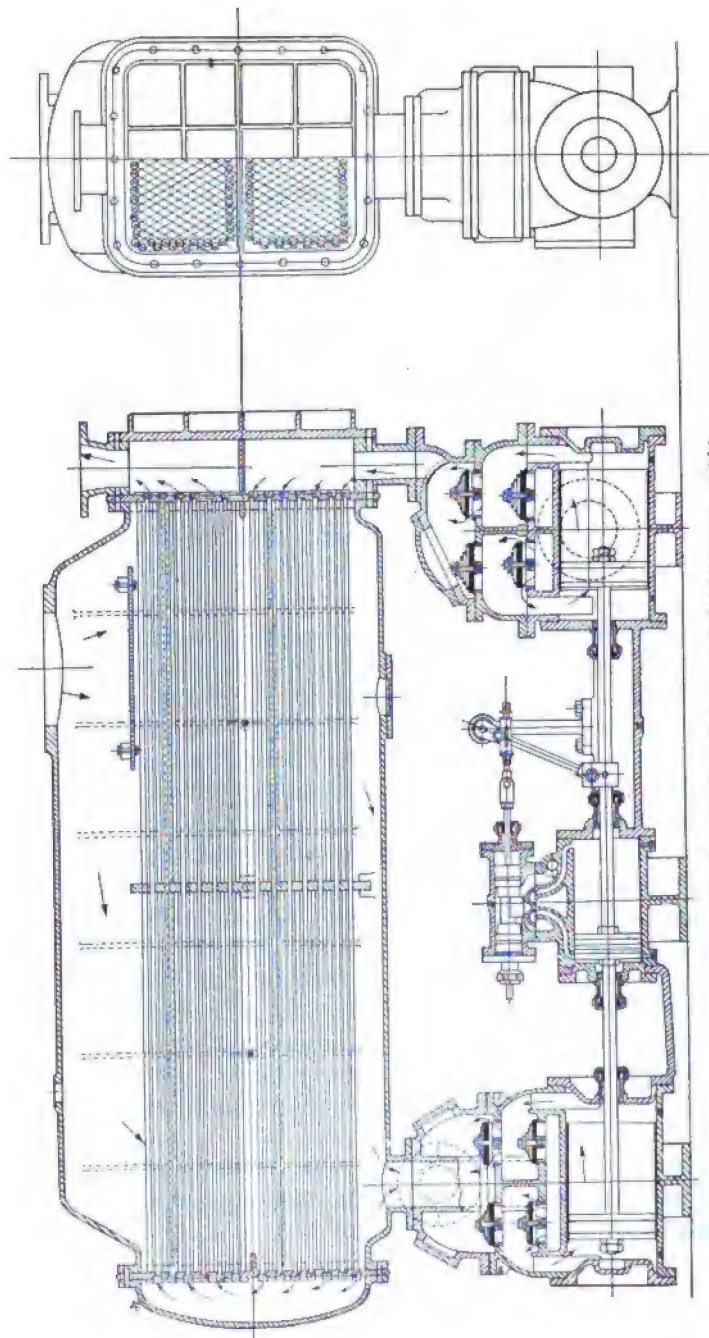
Be economical in the use of injection water; using but enough to keep the desired vacuum and maintain a temperature in your hot well of from 100 to 120 degrees.

Surface Condensers.—Where water is not available suitable for boiler feeding a surface condenser must then be used.

In this type of condenser the steam is condensed in a condensing chamber on the **surface of tubes** through which cold water is made to circulate, and the distilled water from the steam so condensed may then be again fed to the boilers. Where any considerable amount of cylinder oil is used, some provision must be made when surface condensers are used, to remove this oil **before** the water can be fed to the boilers.

In Fig. 188 is shown the usual form of a **surface** condenser mounted on combined air and circulating pumps.

The surface condenser is the modern development of the jet condenser, so called from the introduction of a "jet" or "spray" of cold water into a closed vessel, from which the air has been exhausted, in intimate contact with the exhaust steam, thus causing the same to be condensed. In the **surface condenser** the result is obtained without commingling the exhaust steam and circulating water, so that the latter may be alkaline, salt, muddy or impregnated with impurities, without affecting the quality of the condensed steam. Again, in the "jet" condenser, the air pump must handle both the circulating water and the condensate, introducing an element of danger in the possibility of flooding the engine. In the surface condenser, the air pump performs only its natural duties, namely, maintaining a vacuum and caring for the condensed steam, which, when suitably cleansed of oil, is a pure hot feed water. The heated circulating water may also be utilized for washing and dyeing purposes, as it has not been in contact with the steam and is, therefore, free from oil.



**WHEELER CONDENSER & ENGINEERING CO'S
SURFACE CONDENSER MOUNTED ON COMBINED AIR & CIRCULATING PUMP**

The Wheeler Condenser, as shown in Fig. 188, is made both cylindrical and rectangular in shape. The improved rectangular design is strongly recommended, owing to a special arrangement for reducing the velocity of the steam, together with a large storage capacity, an extremely desirable feature in connection with large units, such as are encountered in electric light and power stations, rolling mills, blast furnaces, dredges, etc., where sudden and variable loads are to be provided for.

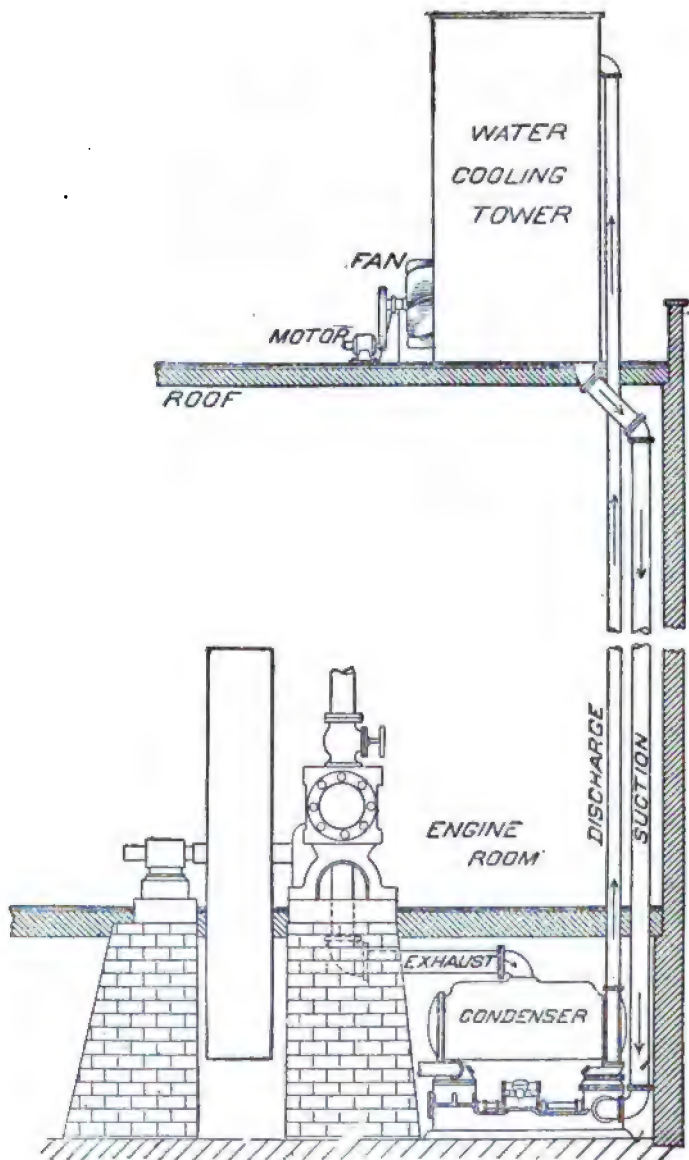
With **either** type of condenser the **quantity** of water to be circulated through the condenser should be from 20 to 40 times the steam to be condensed, depending upon the temperature of the water available for condensing purposes.

A condenser used to condense the exhaust steam from an engine, will reduce the back pressure against which a non-condensing engine must work, so as to **increase** the power of the engine from 20 to 30 per cent when run condensing.

Cooling Towers.—Where it is impossible to get a sufficient supply of water at an economical cost, then a cooling tower or water table is used for the purpose of condensation. This is done by locating same upon the roof, and allowing the atmosphere to cool the condensation, by using a system of mats or slats over the surface of which the water flows in a film to a reservoir which is located at the bottom of the cooling tower.

In this way the water from the condenser is used over and over again. The loss of water by evaporation when this method is used, is only from 5 per cent to 10 per cent, which loss must be supplied with fresh water from some outside source.

In Fig. 189 is shown the general arrangements of a Water Cooling Tower.



General Arrangements of a Water Cooling Tower.

Fig. 189.

In this arrangement the cooling tower is located on the roof of a building.

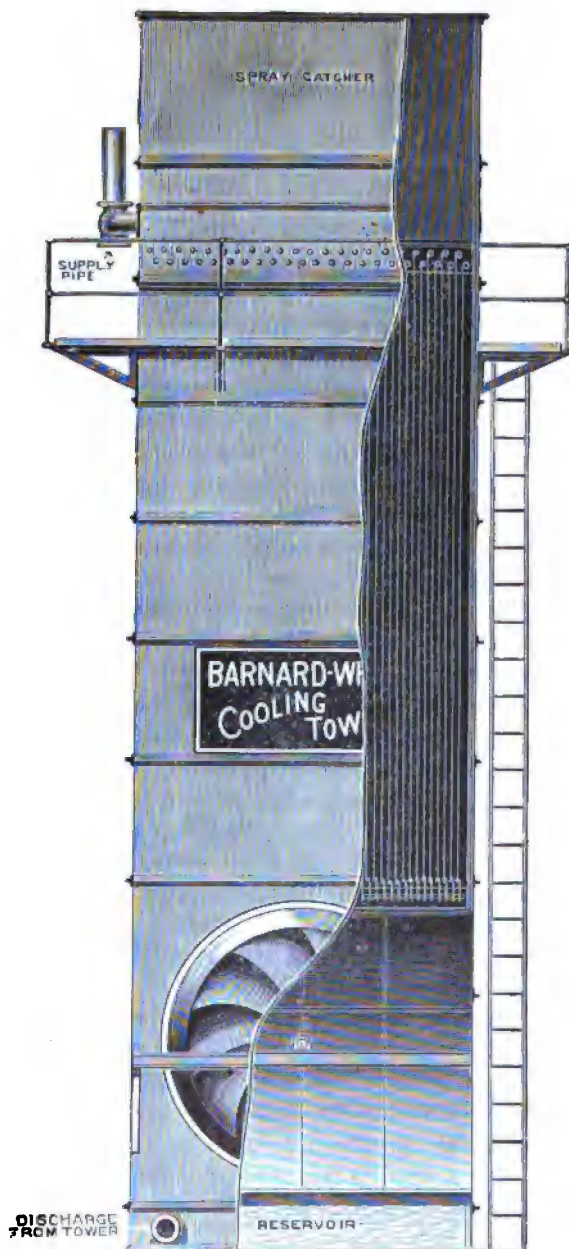
The discharge from the condenser, as indicated by the arrows, is led to the top of the cooling tower where it is cooled and returned to the condenser through the condenser pump, the connection being made direct to the suction pipe of the pump as shown in the diagram.

The hot condensation from the exhaust steam is cooled by making it flow over a series of mats or slats in a thin film to a reservoir located at the bottom of the cooling tower, as has been explained above.

A common reduction of temperature by the use of these towers has been from—say 130 degrees to between 85 degrees and 90 degrees, and when it is remembered that this is accomplished simply by taking advantage of nature's functions, the magnitude and importance of this invention is strongly accentuated.

The field into which this device enters is almost boundless. A mining or any steam plant located where water and coal are hauled or conveyed in an expensive manner is practically compelled to run non-condensing, unless resort is made to the cooling tower, when all the economy of a condensing system is gained at a comparatively small cost. Power house location is greatly simplified. Those which have been placed in remote positions, necessitating long lines of wiring, liable to serious leaks, to say nothing of additional cost of copper feeders, may, with the installation of a cooling tower be located centrally. The same argument applies to artificial ice factories. Brewers have long known the importance of such a device. Owing to their first cost their use is limited to a great extent.

In Fig. 190 is shown the general arrangements of the Barnard-Wheeler Water Cooling Tower.



The Barnard-Wheeler Cooling Tower.
Fig. 190.

Construction.—The tower casing is preferably constructed of steel plates. Within the tower are hung a number of mats of a special steel wire cloth, galvanized after weaving. The pump discharge is led to the top of the tower and distributed by a suitable system of piping to the upper edge of the mats, over the surface of which it spreads in a thin film, compelling a partial interruption of the flow, and continuously bringing new portions of the water to the surface, thereby exposing them to the evaporative and refrigerative effects of the air currents. The mats are practically a metallic sponge, capable of holding a large quantity of water in suspension, which accumulates and drips off into the supply tanks.

To assist the cooling action, the air in immediate contact with the water is set in rapid circulation by means of the fan blower, which forces air into the lower part of the tower and upwards between the mats. This may be driven by any convenient source of power, such as an electric motor, or from a line shaft, or by an independent steam engine.

With the Barnard-Wheeler system of cooling towers and condensers there is no difficulty in reducing the temperature of the condensing water from 40 to 50 degrees, or sufficient to maintain a vacuum of 23 to 25 inches, thus insuring fuel saving and greater efficiency of the plant.

As there is but a small loss due to evaporation—say, not exceeding 3 per cent of the water passing through the tower—steam plants are enabled to operate condensing, independent of a natural water supply.

The operating power requirements of this condensing installation is but $2\frac{1}{2}$ to 4 per cent of the total I. H. P. output of the main engines, according to their size. With fanless tower this ratio is considerably reduced.

Owing to the light weight per square foot of foundation area, this cooling tower is admirably adapted to roof installations, which is an important feature where ground space is not available.

Causes of Imperfect Vacuum.—One of the most serious objections to the use of condensers is the difficulty in maintaining a sufficiently low vacuum.

An imperfect vacuum, that is, a low vacuum, is usually due to one of three causes, being namely: 1, the amount of condensing water may be insufficient; 2, the air pump, which is used to remove the air which enters with the steam, may be **out of order**; 3, there may be **air leaks** in the chamber itself permitting the entrance of air from the outside.

CHAPTER XIX.

COMPOUND ENGINES.

Advantages of Compounding.—A compound engine has **two** cylinders of different size. Steam is admitted first into the smaller one, called the **high pressure cylinder**, and, after a certain amount of expansion has taken place is exhausted into the larger or **low pressure cylinder**, where it is further expanded before being finally exhausted into the atmosphere or condenser.

The object of compounding engines, is to obtain **economy** in the use of steam by reducing the **cylinder condensation**.

In the single engine, a great portion of the heat of the entering steam is given up in heating the wall of the cylinder. This loss of heat greatly lowers the economy of the engine, and it is to avoid this as much as possible that engines are compounded. The condensation of the steam by the much cooler walls of the cylinder is called cylinder condensation, and it is to lessen this as much as possible, that the many different types of engines have been designed.

In the single engine, a large part of the heat which has been given up to heat the cylinder, is again taken up by the condensed steam during expansion and the exhaust stroke, but finally is wasted through the exhaust pipe. In the **compound engine**, all the heat which is lost during admission, and which is again taken up by the steam during expansion and exhaust, is not lost by being discharged into the atmosphere or the condenser, but is discharged into the **low pressure cylinder** where it is used again in heating that cylinder, and

therefore decreases the amount of the entering steam that is so wasted.

In compound engines, the only loss from cylinder condensation is therefore that which takes place in the **low pressure cylinder**, as the steam is discharged from the high pressure cylinder before its temperature is much reduced. We therefore see from the foregoing explanation, that the cylinder condensation in the compound engine will be considerably less than one-half of that in the single engine.

There is also a **mechanical advantage** in compounding the engine, as two cranks may be used, set at right angles to each other, so that when one is on a dead center, the other is at a position of nearly its greatest effort. This makes a dead center impossible, and thereby enables the engine to run more uniform.

By thus compounding an engine at least **20 per cent** can be saved, that is, the compound engine is 20 per cent more economical than the single engine.

Construction.—The low pressure cylinder must be made **larger** than the high pressure cylinder, on account of the pressure of the steam being less when it reaches this cylinder than when it entered the first cylinder. This cylinder must therefore contain a greater volume of steam, and must have a greater piston area against which the steam can act.

Systems.—There are several different systems of compounding an engine, being namely, 1, the **tandem compound**, in which both cylinders are in line and both pistons arranged upon the same rod; 2, a **cross compound**, which consists of practically **two** engines, side by side and connected to the same shaft. In this form of compounding, both cylinders operate **separate** cranks, which may be set at right angles to avoid dead centers

and to distribute the load more evenly about the crank shaft, or, as is rarely done, the cranks may be set opposite each other.

In Fig. 191 is shown a sectional view of a tandem compound and a cross compound engine with proper crank connections.

The Receiver.—This consists of an enclosed vessel of at least the same capacity as the high pressure cylinder, and into which the **high pressure** cylinder exhausts. The steam passes from the receiver into the low pressure cylinder.

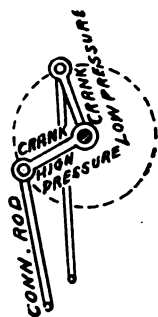
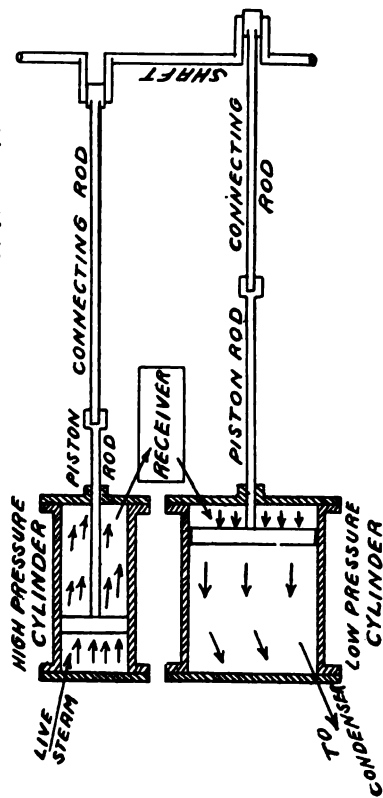
A receiver is necessary for those engines, the cranks of which are set at right angles. For instance, in the two cylinder engine the cranks would be placed 90 degrees apart, and therefore one cylinder could not take steam during the time that the other cylinder was exhausting. Therefore, an enclosed chamber, or **receiver** as it is called, is necessary in which to store the steam until it is wanted.

Most compound engines are therefore supplied with a receiver, though in a **tandem compound** engine it is not a necessity, as the cranks are not set at right angles, and therefore **both** pistons start at the same time on their stroke, and hence the steam can pass directly over from the high pressure cylinder into the low pressure cylinder. If a tandem compound cuts off early in the stroke, a receiver will then be necessary.

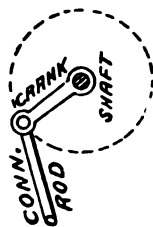
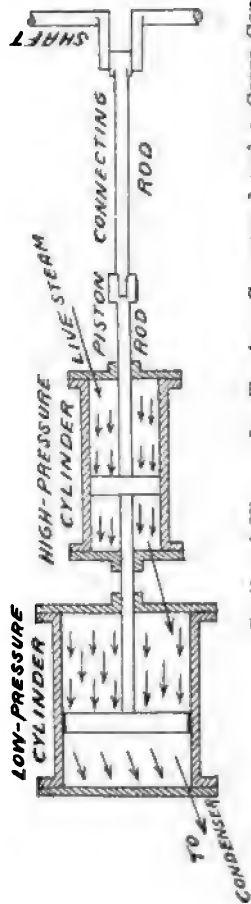
In a **cross compound** engine the cranks are almost always set at right angles, and therefore the leading cylinder has completed one-half its stroke before the other begins, consequently there must be a receiver to take care of the high pressure exhaust.

In Fig. 191, a receiver is shown in connection with a cross compound engine.

CROSS COMPOUND



TANDEM COMPOUND



Sectional Views of a Tandem Compound and a Cross Compound Engine, with proper Crank Connection.

The Reheater.—This is a modification of a receiver, containing coils, or nests, of small pipes through which the high pressure steam circulates and becomes **reheated** before being again used in the low pressure cylinder.

Construction.—The exhaust from the high pressure cylinder enters at one end of the heater, and is compelled by baffle plates to flow over and around these tubes, finally passing out at the other end of the chamber into the low pressure steam chest. Live steam at boiler pressure is made to pass **through** the tubes around which the exhaust steam circulates, and in this way the exhaust from the high pressure cylinder can be reheated before it enters the low pressure cylinder. The usual form of a reheater consists of a cast iron or wrought iron shell, having at one end a tube plate secured between the shell and cover. A large number of wrought iron boiler tubes are expanded into this tube plate, and these boiler tubes are expanded at the other end also into a tube plate which is bolted to the head. One end of the reheater is closed by a cover through which a steam pipe and an air drain pipe pass. A drain pipe is inserted through the lower head and connected to a trap. The drain from the shell is also led to a trap.

Economy.—It is not **always** economy to use a reheater, as the amount of **live steam** used, may cause a **loss** instead of a gain.

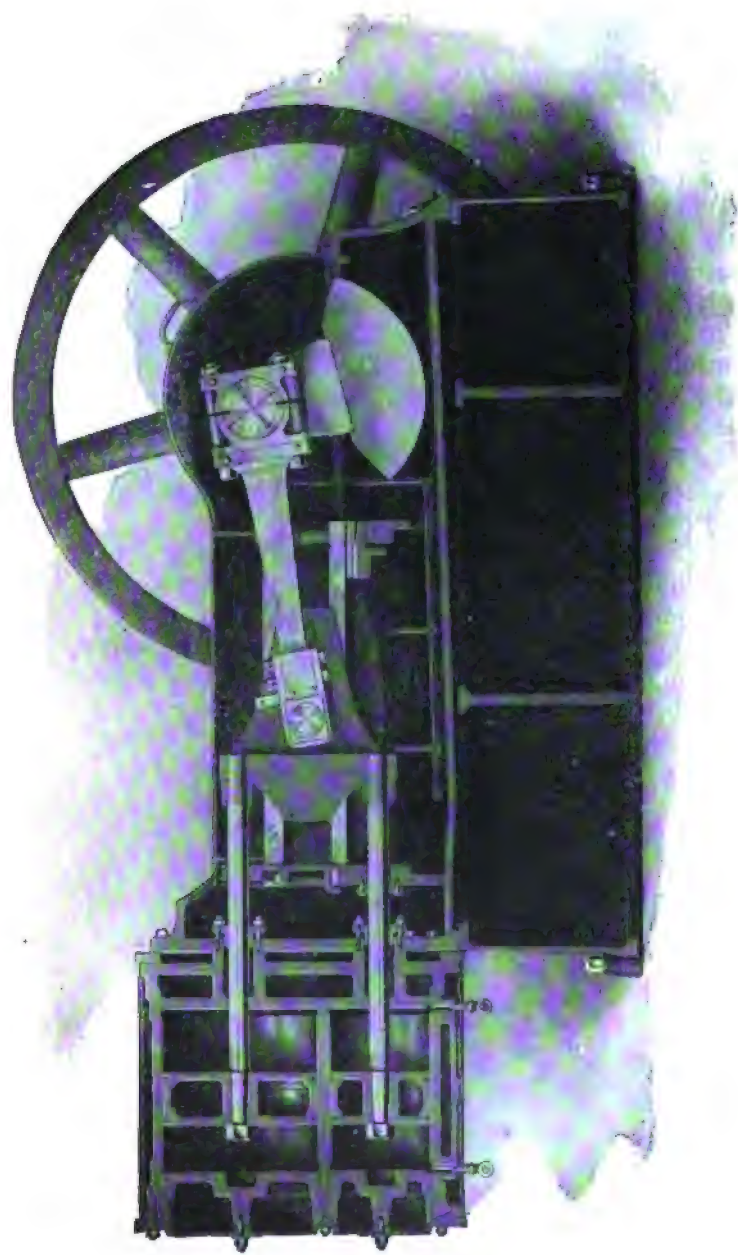
Test.—In order to determine if there is any economy in its use, place a thermometer in the low pressure exhaust. Should the temperature of the exhaust steam be **higher** than that corresponding to its pressure, the reheater is wasting steam, and should be abandoned.

THE AMERICAN DUPLEX COMPOUND ENGINE.

The most conspicuous features of this engine, as seen from Fig. 192, are its **compactness** and **simplicity**. It will be seen from this cut that it requires no more floor space than the simple engine, and the valve gear, consisting of a **single** valve rod and valve, has exactly the same number of parts as the valve gear of a simple engine.

Progress in engineering is generally either in the direction of a better result, or a simpler or more compact machine, and generally a gain in one of these directions is accompanied with a loss in the other, so that the two must be balanced against each other in determining the real advantage. This **Duplex Compound Engine** is one of those happy combinations in which a great gain in simplicity and compactness is also attended with an appreciable gain in efficiency.

The Valve.—The valve used in this engine is an improved form of **piston valve**, which provides a very practical means of adjustment for wear. It is well understood that the wear of a piston valve in a horizontal engine occurs on the lower half, and is caused by the friction due to the weight of the valve. Part of the wear is on the valve and part in the bore of the valve chest, and the leakage is over the upper half of the valve through a crescent shaped opening. The lower half of the valve which has been worn by contact with the bore of the valve chest, still fits the bore and is practically steam tight, and the upper half of this valve would fit the upper half of the bore perfectly if it could be brought into contact with it. This is just what is provided for in the construction of this valve, by splitting the valve horizontally, so that the upper half may be separated



The American Duplex Compound Engine.

Fig. 192.

from the lower and brought into contact with the upper half of the bore. This makes an **oval**, not a cylindrical valve, but a cylindrical valve would no longer fit the bore, which has been worn into an oval. To provide for the adjustment of this valve, thin sheets of rolled copper are placed between the halves.

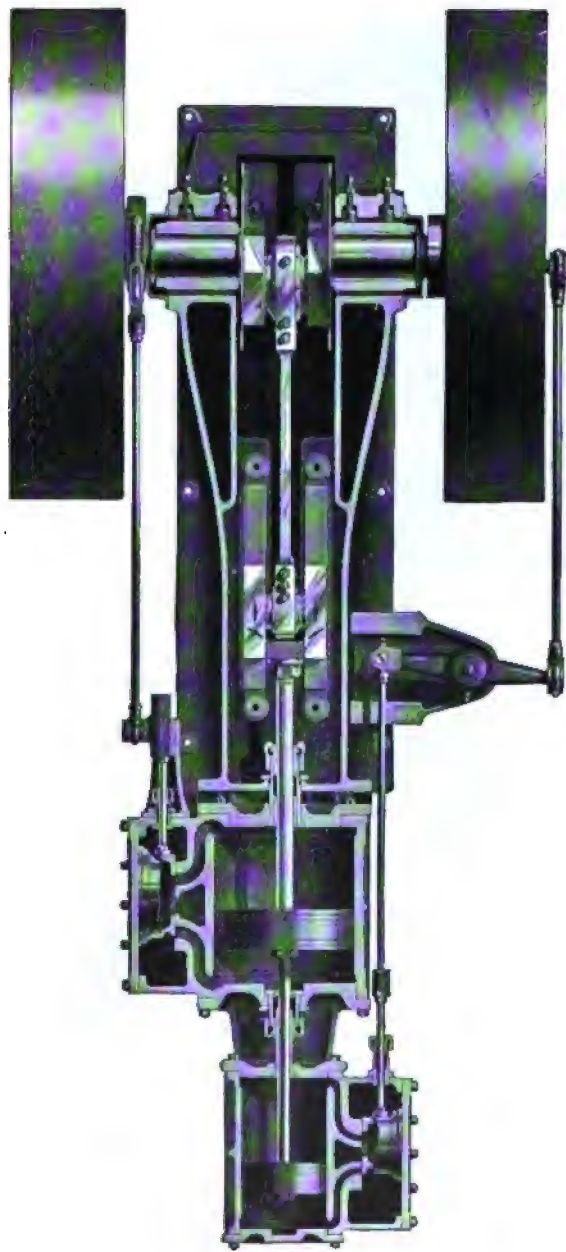
In Fig. 193 is shown a longitudinal section of the Skinner Tandem Compound Corliss Engine.

In Fig. 194 is shown the Fulton Cross-Compound Corliss Engine.

In Fig. 195 is shown the St. Louis Cross-Compound Belted Engine, the tandem type of which engine has been described.

In Fig. 196 is shown the McIntosh-Seymour Cross-Compound Vertical Engine. The general construction of this engine has also been described.

In Fig. 197 is shown a sectional view of the **valves** of a Compound Ideal Engine, the valve on this engine having been heretofore described.



Longitudinal Section of the Skinner Tandem Compound Engine
Showing Valves.

Fig. 193.

CHAPTER XX.

QUESTIONS AND ANSWERS ON PRECEDING CHAPTERS.

Q. What is a steam engine?

A. It is an apparatus for converting heat into mechanical power.

Q. Who constructed the first practical engine?

A. Thomas Savery in the year 1693.

Q. For what purpose was it used?

A. For pumping water out of a mine.

Q. Who greatly improved upon this engine, when and how?

A. Newcomen in the year 1705 by using a piston which worked in a cylinder.

Q. Who greatly improved upon the Newcomen engine, introducing the first type of the modern engine?

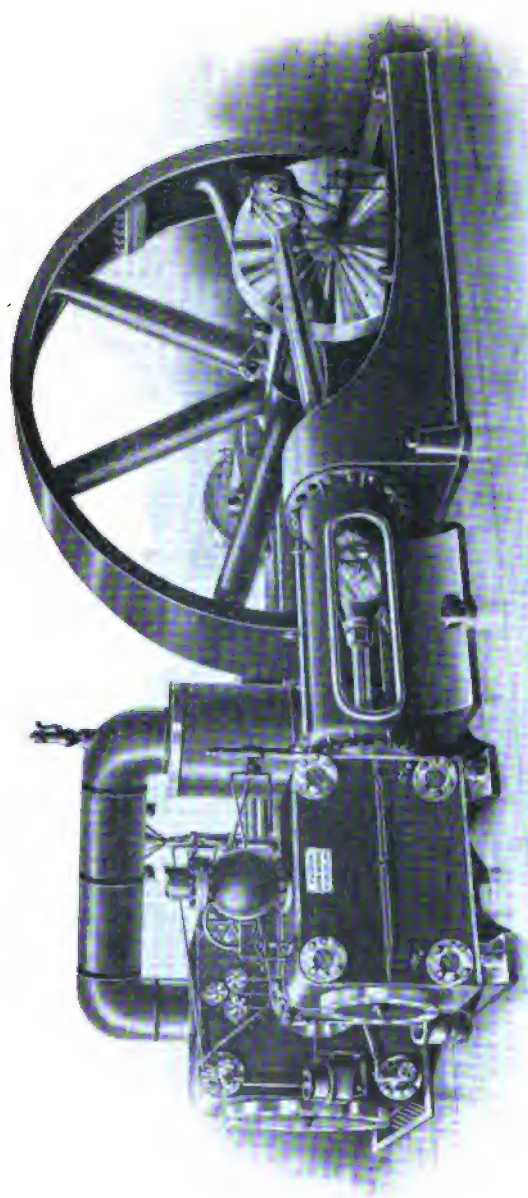
A. James Watt in 1764. He first introduced the use of the **separate** condenser and a **closed** cylinder, together with a great many changes which have been but little improved upon even to the present day.

Q. How are engines classified?

A. According to the work for which they are built, being viz.: (1) stationary, portable, etc.; (2) from the arrangement of the cylinders, as, simple, compound, triple expansion, etc.; (3) according to the character of the valves to control the distribution of the steam, as plain slide valve, automatic cut off, Corliss, etc.; (4) according to the motion of the piston, as reciprocating and rotary.

Q. How are these divisions subdivided?

A. Into (1) condensing engines, (2) non-condensing engines, (3) single acting engines; (4) double acting engines.



The Fulton Cross-Compound Corliss Engine.
Fig. 194.

Q. What is a simple engine?

A. It is an engine in which the steam is used **expansively** in only **one** cylinder.

Q. What is a compound engine?

A. It is an engine which has **two** cylinders, the steam being expanded **twice** before its final discharge.

Q. What is a non-condensing engine?

A. It is an engine in which the steam after having been expanded in the cylinder is discharged into the atmosphere, or into a heating system.

Q. What is a condensing engine?

A. It is an engine in which the steam after having been expanded in the cylinder is discharged into a condenser where it is brought in contact with some cooling substance, by which it is **condensed** and a partial vacuum produced behind the piston.

Q. What is the object of so condensing the steam?

A. It is to remove as much as possible the **back pressure** on the piston, and to thus increase the mean effective pressure on it throughout its stroke.

Q. What are the reciprocating parts of an engine?

A. They are all the parts which move **back and forth** either in a horizontal or vertical direction, being viz.: (1) the piston, (2) the piston rod, (3) the cross-head, (4) the connecting rod.

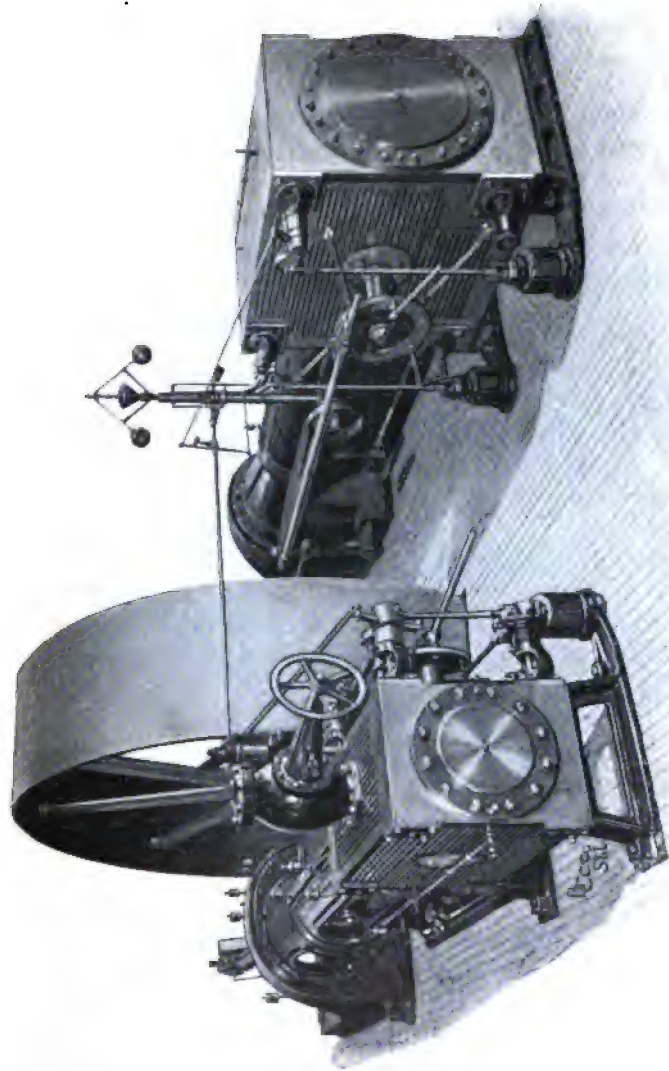
Q. What is the **cylinder** of an engine?

A. It is that part of the engine in which the piston moves.,

Q. What is meant by the term head-end and crank-end of the cylinder?

A. The head-end is the end farthest away from the crank shaft, while the crank-end is the end nearest the crank shaft.

Q. What is meant by the **stroke** of an engine.



The St. Louis Cross-Compound, Belted Engine.

Fig. 195.

A. The distance passed over by the piston in moving from one extreme position in the cylinder to the other.

Q. What is meant by the **valve gear** of an engine?

A. The mechanism by which the steam is distributed.

Q. What composes the valve gear of an engine?

A. The distributing valves, the eccentric, the eccentric strap, the eccentric rod, the rocker, and the valve stem.

Q. What is the eccentric, and what is its purpose?

A. It is a disc or crank keyed to the shaft so that its center and the center of the shaft do not coincide. It is used to operate the distributing valve or valves.

Q. What is a single valve engine, and what is a four-valve engine?

A. A single valve engine is one in which a single valve controls the admission and distribution of steam for both ends of the cylinder, while a four-valve engine is one which has separate valves for the admission of the steam to the cylinder, and for its discharge or exhaust.

Q. What is meant by the **cut-off** of the valve?

A. It is the point of a piston's travel at which the steam admission port **closes**, no further steam being admitted to the cylinder during the remainder of the stroke.

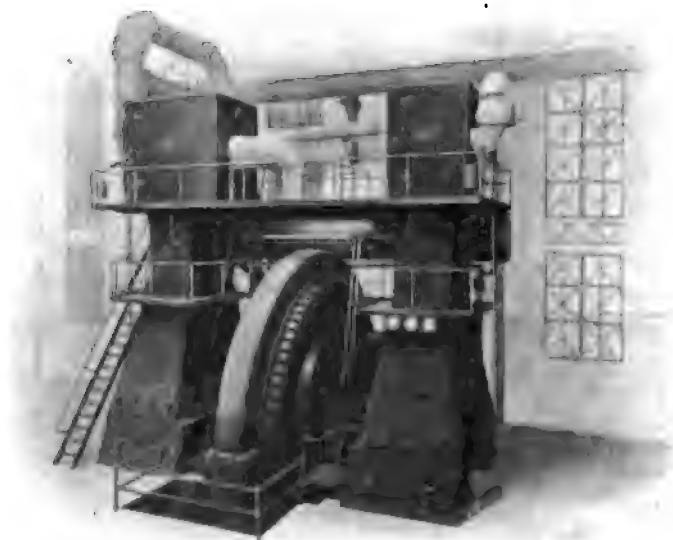
Q. What is the object of cutting off the admission of the steam?

A. So as to allow for expansion of the steam, thus saving steam which means the saving of **fuel**.

Q. What is the purpose of **outside lap** on a valve?

A. In order to cut off the steam before the piston completes its stroke, and thus allow expansion.

Q. What is the purpose of **inside lap** on a valve?



**The McIntosh-Seymour Cross Compound Vertical Engine.
Fig 196.**

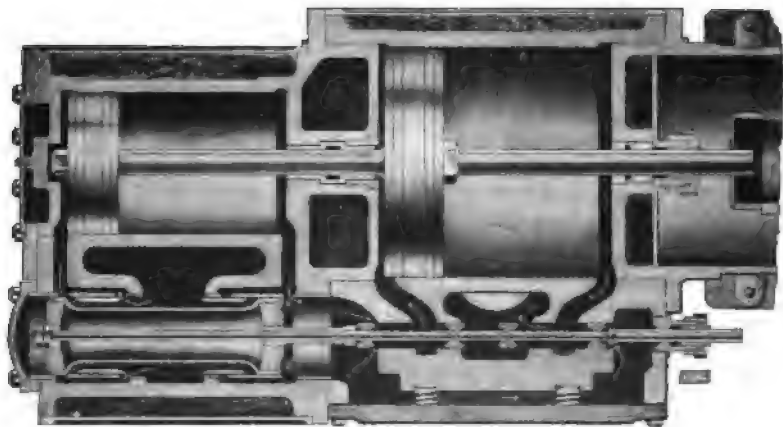
A. It is to close the exhaust port before the piston reaches the end of the return stroke, thus increasing the compression and forming a cushion of steam against which the piston strikes.

Q. What is meant by **lead**?

A. It is the amount that the valve leads the crank, for it is the space the steam port is open when the engine is on the center.

Q. How is the size of an engine indicated?

A. By the length of the **stroke** and the **diameter** of the cylinder.



Sectional View of Valve of Compound Ideal Engine.

Fig 197.

CHAPTER XXI.

PUMPS.

Use.—Pumps vary greatly in design, depending on the character of work for which they are constructed.

They are now made to handle water, beer, molasses, acids, oils, melted lead, and such gases as air, ammonia and oxygen.

The different types used to cover this large field of work are defined as chain, diaphragm, jet, centrifugal, rotary and cylinder pumps.

It is only the last three types, viz.: rotary, centrifugal and cylinder pumps that are generally used in the field covered by this work.

Steam Pumps.—By steam pumps we mean those in which the propelling force is **steam**, and which is applied to the movement of the water, or other liquid, **without** the intervention of belting or gear wheels. Steam pumps are divided into two general classes, viz.: 1, direct acting pumps; 2, fly wheel pumps.

Direct Acting Pumps.—By this is meant a steam driven pump in which there are no revolving parts, such as shafts, cranks and fly wheels, the pressure of the steam being transferred to the piston or plunger through the use of a continuous rod or connection.

The direct acting steam pump was invented and developed by Henry R. Worthington in the year 1840.

The chief **objection** to the direct acting pump arises from the action of the piston or plunger being **intermittent**; that is, the column of water is started into motion at the beginning of each stroke, and comes to a **standstill** at the end of each stroke, thus not only making the flow of the water irregular, but subjecting the pump and the connecting pipe to serious strains.

Duplex Pumps.—In order to overcome the intermittent action of the single direct acting pump, about the year 1845 Mr. Worthington brought out what is known as the **duplex pump**. This is also a **direct acting** pump, the construction of the steam and water ends differing but slightly from that of the single direct acting pump, but the **mechanism** that operates the steam valve is entirely different, and the result produced upon the movement of the water or liquid also differs, as with this pump a **continuous discharge** is secured.

A duplex pump is nothing more than a **combination** of two single direct acting steam pumps coupled together, the steam valve of one being operated by the piston of the other pump.

The effect of this arrangement is to produce a **steady** flow of the water, or liquid, without the usual strains produced when the flow of the same is suddenly arrested and then started again, as is the case in single direct acting pumps.

In duplex pumps the two pistons move in **opposite** directions, making the action of the pump **continuous**. The valve has neither outside or inside lap, as there would be danger of the pump sticking on centers, and hence the steam cannot be used expansively. The steam valve is carried along by coming in contact with check or lock nuts placed on the valve stem.

Lost Motion.—In order to arrest the steam piston when it completes its stroke, and allow the other pump time to pick up the motion, thereby preventing the pump stopping altogether, a certain amount of **lost motion** between these check or lock nuts must be allowed. Should there not be **sufficient** lost motion, the pump will **short stroke**, if **too much** lost motion, the piston will knock out the opposite cylinder head, or will stop on

center. The lost motion allowed together with the auxiliary valve, simply take the place of a **fly wheel** to carry the pump over its centers.

Rule.—The rule is to allow as much as one-half of the width of the steam ports on each side of the lock nut, for lost motion.

Fly Wheel Pumps.—Are those pumps which rely upon a fly wheel to carry them over their centers. Owing to their many disadvantages they are not in general use.

Classification.—Pumps are divided into two general classes, viz.: (1) those having their valve gear outside, and (2) those having the valve gear on the inside, and hence having no moving parts visible except the piston rod.

Pumps are further divided into **single acting** pumps, which do their work through only one end of the cylinder; and **double acting** pumps, which is simply an engine and pump combined. In this latter class of pumps, the motion of the piston in one direction causes an **in-flow** of water and a discharge at the **same** time at the other end, and on the return stroke the action is reversed, as the discharge end becomes the **suction** end. The pump is therefore double acting. The single acting pump is not in general use.

Ends.—The two ends of a steam pump are designated as the **steam end**, which is a complete steam engine, and the **water end** into which the water is drawn, and from which it is discharged by the piston or plunger.

To Adjust the Valves of a Duplex Steam Pump.—The steam chest cover must first be removed, and the glands in the stuffing boxes of the piston and valve rods be slackened so as to permit the rods to be moved **freely** through the packing. Bring the rocker arms into

a **vertical** position, as shown in Fig. 207. While this can be done **without** the use of a plumbline, for accurate work it should be used. When the levers are **plumb**, they occupy the position known as **mid-stroke**, and, were it not for the play necessary between the valves and the lock nuts on the valve stem, the valves would occupy the corresponding position known as **mid-travel**. As pump valves have no lap, when they are placed at mid-travel the ends of the valves should just cover the steam ports, the edges of the valves and the outer edges of the steam ports being then in line.

After placing the rocker arms plumb, measure the **width** of the steam port, and then set the valve squarely over the port, so that both steam ports on both sides of the pump will be entirely closed.

The space between the nuts and the lugs on the back of the valve should be equal to one half the width of the steam port, that is, if the valves are now to be moved in either direction, the steam ports would be **one-half open**.

As the valves will now be in a position to entirely prevent the admission of steam into the cylinder, it will be necessary to move at least one of the valves so as to open one of the steam ports.

The chest cover may now be put on, and the stuffing box glands tightened sufficiently to prevent leaking.

As the piston is in the exact center of its travel when the rocker arm is vertical and the valve covers both ports equally, the valves can therefore be adjusted by placing the **piston** in the middle of its travel. To do this, move the steam piston towards one of the cylinder heads until it comes in contact with it, and make a mark on the piston rod at the face of the stuffing box. Then move the piston to the opposite end of the cylinder and

make another mark on the piston rod. Then half the distance between these two marks is the middle of the travel of the piston, and it is only necessary to move the piston back until the **middle** mark is at the face of the stuffing box to center the piston.

In Fig. 208 is shown the proper position of the valve at the commencement of the stroke. As the valve has neither lap nor lead, the steam port is wide open, and at the opposite end the **exhaust** port is wide open.

Cushion.—In Fig. 209 is shown a method of cushioning the steam piston of a pump by the use of **two ports** at each end of the cylinder, instead of only one port as customary with slide valve engines. It will be seen that the exhaust is closed by the valve passing over first one port and then the other; in this way the compression of the steam is made gradual by the forming of a steam cushion between the piston and the cylinder head, thus arresting the motion of the piston gradually, and without shock or jar. A dash relief valve, not shown in the cut, is placed between these two ports at each end of the cylinder, which valve is regulated from the outside.

Construction of the Water End of a Steam Pump.—

The construction of the **water ends** of a single cylinder and a duplex pump is practically the same. As shown in Fig. 210, the **water valves** are carried by two plates or decks, the suction valves being attached to the lower plate or deck, and the delivery valves to the upper one.

The upper deck, and sometimes both decks, are removable. The valves are secured to the decks by means of bolts or long machine screws, which are screwed into the **bridge** across the port in the plate.

The valve works up and down on this bolt, it serving as a **guide** for the valve. A conical spring is employed

to hold the valve firmly to its seat, the spring being held in position by the head of the bolt, as can be seen from Fig. 210.

Water Valves.—These valves are of the flat disc type, with a hole in the center to enable the valve to raise easily on the bolt, which serves a double purpose of acting as a guide to the valve, and also to limit the travel, or lift, of the valve.

Lift.—In Fig. 210 is shown the lift of the valves, by which is meant the height that they are raised from their seats by the force of the incoming water. The lift of the valve is proportionate to the piston speed at which the pump is run, and it should be as **small** as possible, without causing too much frictional resistance to the water.

Slippage.—Pump slippage is a term used to denote the difference between the **estimated** and the **actual** discharge of the pump, and is generally expressed as a percentage of the calculated discharge. Thus when the slippage is given as 20 per cent, it indicates that the loss due to the slippage amounts to 20 per cent of the **calculated** discharge.

Slippage is mainly due to the time required for the suction and the discharge valves to close, and also to **excessive** speed. When the piston speed is too high, the water cannot enter the pump fast enough to **completely** fill the cylinder, and in consequence only a **partial** filled cylinder of water is delivered at each stroke.

This slippage, which is also due to the improper seating of the valve, affects considerably the **efficiency** of all pumps.

Air Chambers.—In order to steady the discharge of the water, air chambers are used on almost all pumps. The air which is contained in the water, being lighter than the water rises and fills this air chamber which is

usually placed at the highest point on the discharge chamber, and in this way forms a **cushion** to steady the flow of the water passing through the pump.

Operation.—The operation of the water end of a pump may be readily understood by referring to Fig. 210, which shows the **movement** of the water valves. The suction valves prevent the **return** of the water after it has entered the cylinder, and the discharge valve permits the **outward** passage of the water, but does not permit its return.

The water is not actually raised by suction, but by the **pressure** of air on the water outside the pump. The piston, or plunger, of the pump **exhausts** the air from the cylinder, thus forming a vacuum, and the **unbalanced** weight of the water causes it to rise within the pump, or pipe supplying the pump, filling the **vacuum** so formed. The limit of this lift for water is about 33 feet, because water of 1 inch area at this height has about the weight of the atmosphere, viz.: 14.7 pounds. Pumps rarely are in such perfect condition to lift water this height, as to do so all pipes and valves would have to be perfectly **air tight**. Ordinarily, pumps will not lift water more than from 22 to 25 feet.

As a vacuum is necessary for the operation of a pump where water or a liquid must be **lifted**, it is impossible for a pump to lift **hot water**, as the **vapor** therefrom fills the vacuum as fast as it is formed by the piston. Therefore, where a pump is required to handle very hot water, it must be placed **below** the water supply, so that the water will flow into the pump. Under such conditions, a pump can handle water whose temperature is 212 degrees, or above, without any special difficulty. The **most necessary** condition for the satisfactory operation of a pump, is a **full and steady supply of water**.

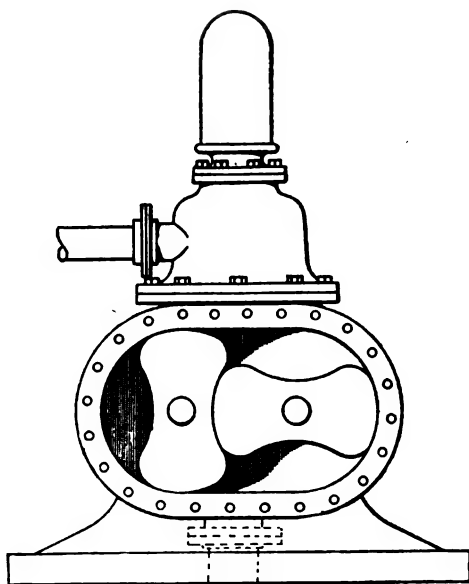
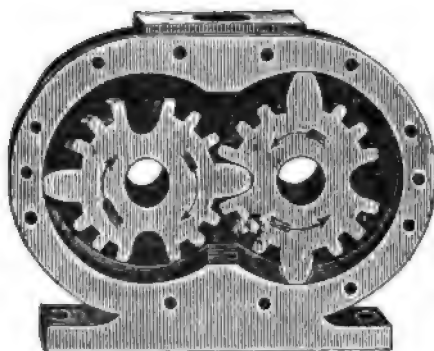
Pipe Connections.—The pipe connections of a pump should in no case be **smaller** than the openings in the pump, and both the delivery and the suction pipes should be as **straight** as possible. The flow of water in the suction pipes should not exceed 200 feet per minute, and not more than 500 feet in the delivery pipe for a duplex double acting pump.

Boiler Feed Pumps. Such pumps as are used for supplying steam boilers with their necessary water supply, are designated as **boiler feed** pumps. For ordinary pressures, they are usually made of the piston pattern.

The cylinders are generally brass lined. The valves are brass or of hard composition, with composition springs, as the pump must be suitable for handling hot water. Both single cylinder and duplex pumps are used for boiler feeding, but the duplex pump is more generally used, as it gives a most continuous action under all circumstances.

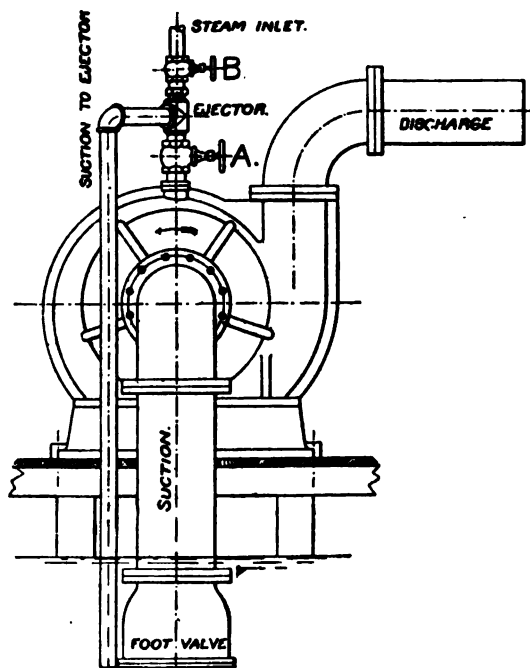
Selection of Pump.—As the **service** to which a pump is to be applied determines its type and general construction, when ordering or making inquiries as to the pump for any particular work, full information should be given in answer to the following questions, viz.:

1. For what purpose is the pump to be used?
2. What is the maximum number of gallons to be pumped per hour?
3. What is the liquid to be pumped? If water, is it hot or cold, clear or gritty, fresh, salt, alkaline or acidulous?
4. What distance, vertically and horizontally, will fluid be drawn on suction side of pump?
5. To what distance vertically and horizontally, or against what pressure per square inch is the fluid to be forced?



A Rotary Pump.

Fig. 198.



A Centrifugal Pump, Showing Installation.

Fig. 199.

6. What will be the steam pressure at pump? Give lowest steam pressure that pump may have to work with.

7. How many hours per day is the pump to operate, or is it to run continuously?

8. If the pump is to be connected to pipes already placed, give the diameters of the pipes, also number of bends and elbows.

Compound Pumps.—In Fig. 215 is shown a sectional view of a compound duplex steam pump.

Rotary Pumps.—The action of these pumps, as shown in Fig. 198, depends upon the force given to the water, or other liquid, by the action upon it of two tooth wheels, which are made to revolve in an enclosed chamber, each tooth of these wheels acting as a small piston, and pushing the water or liquid ahead of it. The flat faces of these wheels should be made a snug fit between them and the casing, and the edges of the teeth also a good fit against the sides of the casing. These pumps occupy but little space, and are light and inexpensive, but are of low efficiency. They are chiefly used to pump heavy liquids, or water holding in suspension large masses of soft material.

Centrifugal Pumps.—Pumps of this type, as shown in Fig. 199, depend for their action upon the pressure produced by the centrifugal force of the water rotated rapidly by the vanes of the pump. As it is the centrifugal force upon which these pumps must rely for moving the water or other liquid, they are designated by that name.

These pumps are only efficient when working under low lifts, being limited to a lift not exceeding 40 feet. They are well adapted for pumping large volumes of dirty water or sewerage, and are therefore much used for sewerage pumping and dredging.

CHAPTER XXII.

TYPES AND DESCRIPTIONS OF STEAM PUMPS.

Single Cylinder Direct Acting Steam Pumps.—The **single cylinder** pump is preferred by many persons as delivering for a given capacity more water, with less steam used than possible with the **duplex** pump. This is due to the fact that the friction of the single cylinder pump is much less than for the duplex pump. For instance, if the stuffing boxes of one side of a duplex pump are tightened more than on the opposite side, the piston on the tight side will move more slowly, as the valve on that side is actuated by the more rapidly moving piston on the other side, thereby considerably shortening the stroke, which reduces the volume of water delivered corresponding to a given number of strokes per minute.

This is never the case in a single cylinder pump, as its piston never starts on the return stroke until it has traveled the **full length** of its stroke in either direction, since the admission of steam is controlled by one and the same motion of all the reciprocating parts which it operates.

Better economy is also claimed for the single cylinder pump owing to the smaller **radiating surface** for a given capacity, and to the much smaller **clearing space** in the steam end. While the single cylinder pump has only two main ports leading to the cylinder, the duplex pump has four main ports in each cylinder. Of course, this greatly **increases** the amount of clearance, which means a proportionately greater waste of steam.

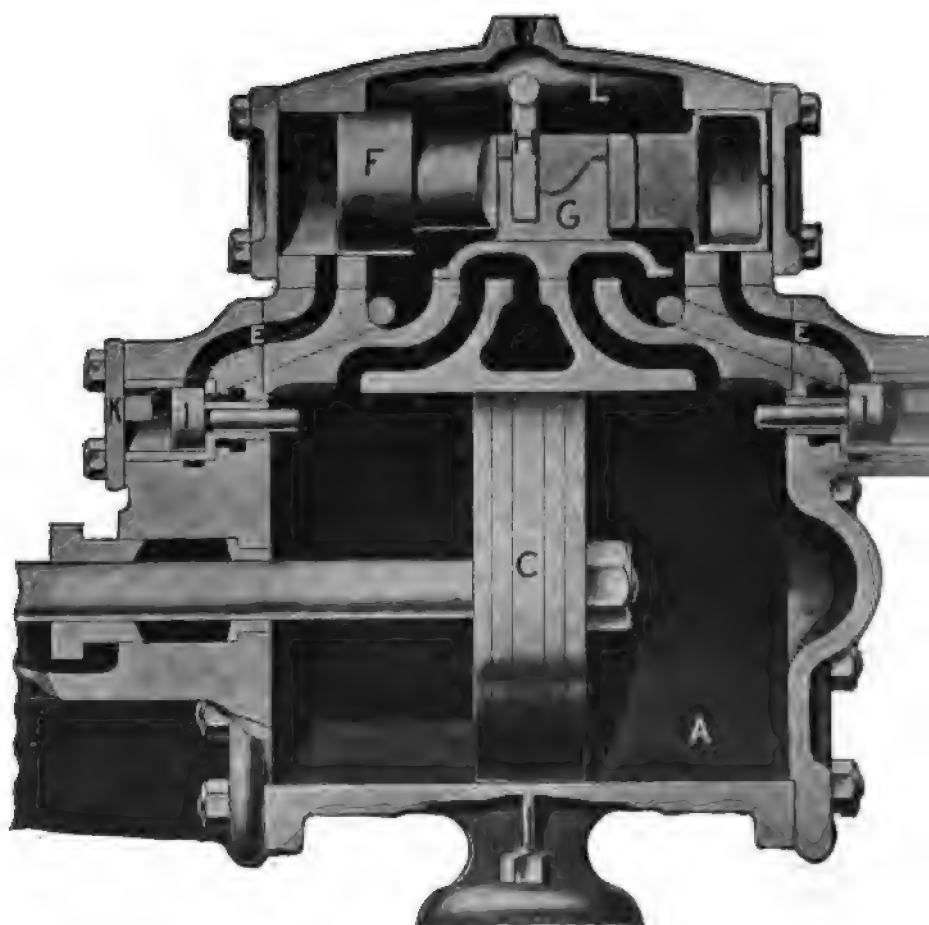
The adjustment and readjustment of the valve is also almost wholly eliminated in the single cylinder pump.

The following is a concise description of the several leading types of the single cylinder direct acting steam pumps, which are in most general use in this country.

The Cameron Steam Pump.—All single, direct acting pumps make use of an auxiliary plunger to carry the main slide valve, which gives steam to the main piston. By means of various devices steam pressure is made to drive this auxiliary plunger backward and forward. In the **Cameron** pump, shown in Fig. 200, the plunger is reversed by means of two plain tappet valves, and the entire mechanism thus consists of four stout pieces only, all working in direct line with the main piston. Simple and without delicate parts, it is the only inside valve gear that is absolutely reliable.

Explanation.—A is the steam cylinder; C, the piston; L, the steam chest; F, the chest plunger, the right hand end of which is shown in section; G, the slide valve; H, a lever, by means of which the steam chest plunger F may be reversed by hand when expedient; II are reversing valves; KK are the reversing valve chamber bonnets, and EE are exhaust ports leading from the ends of steam chest direct to the main exhaust and closed by the reversing valves II.

Operation.—C, the piston, is driven by steam admitted under the slide valve G, which, as it is shifted backward and forward, alternately connects opposite ends of the cylinder A with the live steam pipe and exhaust. This slide valve G is shifted by the auxiliary plunger F; F is hollow at the ends, which are filled with steam, and this, issuing through a hole in each end, fills the spaces between it and the heads of the steam chest in which it works. Pressure being equal at each end, this plunger F, under ordinary conditions, is balanced and motionless; but when the main piston C has traveled far enough to strike and open the reverse valve I, the steam exhausts through the port E from behind that end of the plunger



The Cameron Direct Acting Steam Pump.
Fig. 200.

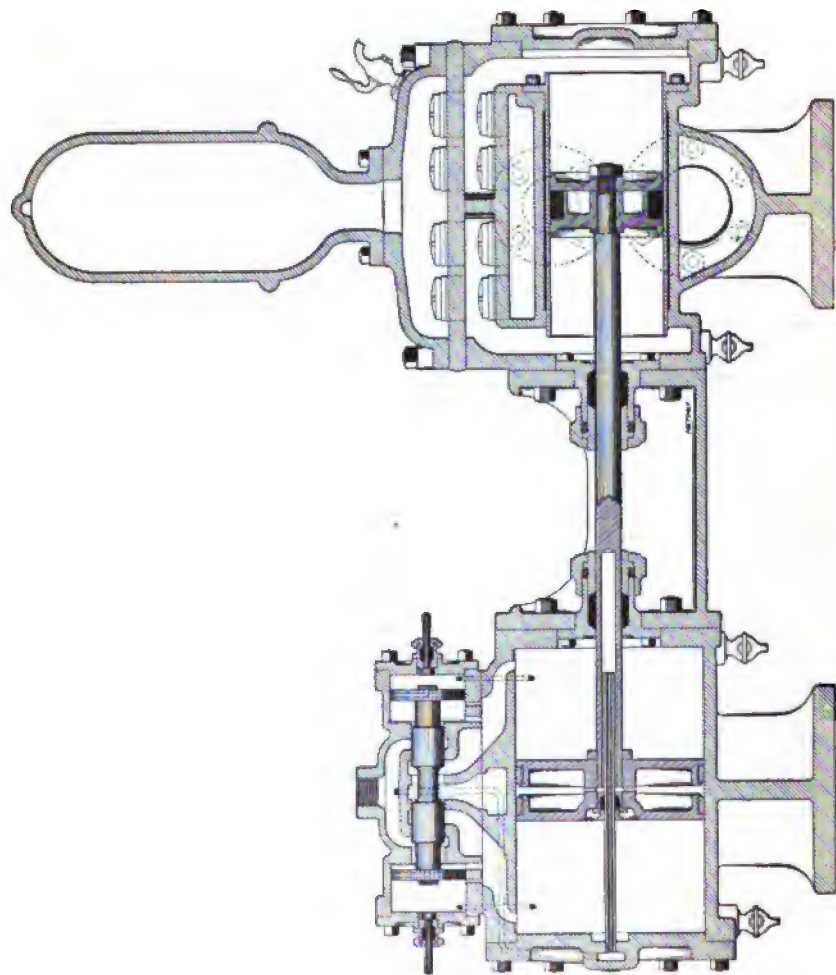
F, which immediately shifts accordingly and carries with it the slide valve G, thus reversing the pump. No matter how fast the piston may be traveling, it must instantly reverse on touching the valve I. In its movement the plunger F acts as a slide valve to close the port E, and is cushioned on the confined steam between the ports and steam chest cover. The reverse valves II are closed as soon as the piston C leaves them by a constant pressure of steam behind them conveyed direct from steam chest through the ports shown by dotted lines.

• **The Marsh Direct Acting Steam Pump.**—In Fig. 201 is shown a sectional view of the interior construction of the larger sizes of **Marsh** pumps. .

The steam entering the chest is passing to the left, through the annular opening formed between the reduced neck of the valve and the bore of the first chest wall. It is thus projected against the inside surface of the valve head before escaping through the port and passing to the cylinder.

Both the pressure and impulse due to velocity, acting on the valve head, operate to close or restrict the admission portage at the annulus, by forcing the valve to the left, or in the direction of the current. On reaching the cylinder, and driving the piston toward the right, the reactive effect of the cylinder steam upon the opposite side of the valve head, entering the outer end of the chest chamber, is pressing the valve toward the right—a movement which would give the admission more portage, and deliver more steam to the cylinder.

The valve then holds a position depending upon the relative strength of the two forces which tend to move it in opposite directions—**admission steam**, which



The Marsh Direct Acting Steam Pump.
Fig. 201.

tends to close the valve, and cylinder steam, which tends to open the valve wider. This constitutes the governing element.

Operation.—Having now explained that the steam is always in a perfectly balanced position, next will be considered how it is reversed at the end of the stroke.

The steam piston consists, as shown, of a spool form, each head of which is provided with a metal packing ring; the interior space forming a reservoir for live steam, which is supplied from the upper chamber of the chest, above the valve, following the passage indicated by dotted lines to the central cap in cylinder cover, through attached tube and hollow piston rod.

This pressure is used only for the purpose of “tripping” or reversing the valve, by admitting steam alternately against the outer surface of the valve heads, through the connecting passages near each end of the steam cylinder.

Caution.—To engineers in charge of Marsh pumps, it is deemed necessary to call attention to the following points:

1. The gasket packing between the steam chest and cylinder must be patterned from the planed surface on top of cylinder (not lower part of chest), carefully duplicating all holes, and making certain that the drilled ports at each end are unobstructed at point of register with corresponding holes in chest, either by dirt or packing.

2. The cylinder cover must be so placed, when bolting to cylinder, that the continuation of passage shown in dotted lines, carrying the trip supply steam to piston, shall register in head and cylinder, and a thin gasket packing be placed under the cover, with a hole to connect the passages.

3. The trip tube stuffing box in steam piston must be repacked occasionally.

The Burnham Direct Acting Steam Pump.—The following is a short description of the Burnham Steam Valve and its operation, as illustrated by the sectional views, shown in Fig. 202.

Fig. 1 is a top view of the pump, showing auxiliary valve and chest in section.

Fig. 2 shows a vertical section through the pump.

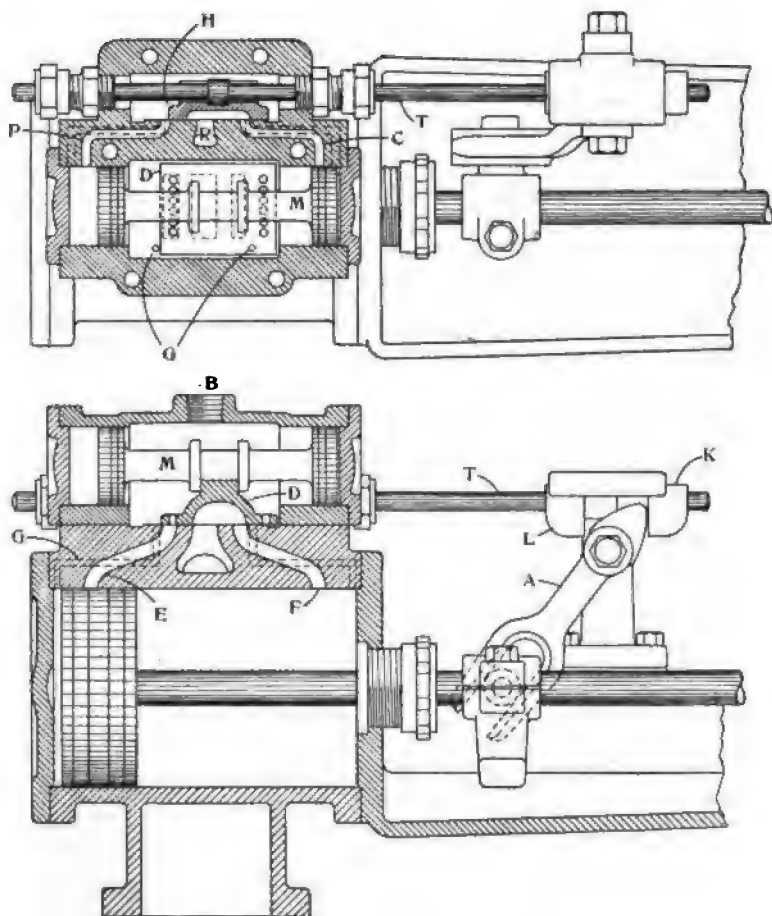
Live steam enters steam chest at B and is admitted to the cylinder, alternately, through port E and port F.

At the beginning of the stroke, port E is covered by the piston, as shown in cut; a pre-admission port G is provided, which admits only enough steam to give the piston an easy start; but when the steam piston has moved far enough to uncover the port E, it receives the full steam pressure and moves at its normal speed until it covers the port F, when it traps the remaining exhaust steam in the end of the cylinder, and thus forms a cushion, giving the piston rod an easy stop.

The gear is positive in action and is operated by a slotted lever A, moved by a roller attached to the piston rod. This lever A, alternately, moves blocks K and L, both of which are fastened to valve stem T, which in turn moves auxiliary valve H (Fig. 1) in the direction opposite to the motion of the piston.

At the end of the stroke, the auxiliary valve H will be moved to the left far enough to open port P to exhaust through R, at the same time admitting live steam through port C. This causes the chest piston M to move instantly, carrying main valve D with it, and reversing the motion of the pump.

The chest piston has a pair of preadmission ports similar to those described above for the main piston, and



The Burnham Direct Acting Steam Pump.
Fig. 202.

are for the purpose of giving a steam cushion to insure quiet action.

Blocks K and L are independently adjustable on rod T, enabling the engineer to make the piston run as close to the heads as he desires, and to make adjustment to compensate for wear.

The advantages of this valve gear are: A momentary pause of the piston at the end of each stroke, causing the water valves to seat quietly without shock or jar; a slow initial movement of the piston, whereby the water columns are started gradually, relieving the pump and piping of undue strains; a steam pressure on the main steam piston proportioned to the amount of work that it has to do; and immunity from damage in case of accident.

Directions to Set Valve.—While testing the Burnham pump at the factory, the valve is adjusted to give an ample amount of clearance to the steam piston, and all pumps should be readjusted after they have been in operation for a time, to suit the conditions and duties required.

You will find on tie rod (see cut), upon which moves the piston rod guide, a mark at each end, indicating the extreme travel of the piston.

If you find that the pump does not run as close to the mark as practical, loosen the set screw in cam block on the opposite side of the actuating lever from which you wish to lengthen the stroke, and move the cam block away from the point of contact of actuating lever.

This will allow the piston to move farther before opening the valve.

You will find that by moving this cam block 1-16 of an inch, it makes quite a perceptible difference in the

piston travel, according to the size of pump to be adjusted.

If pump should travel too close to the marks, which would cause it to hesitate and stop at the end of stroke, you should move these cam blocks toward the point of contact of actuating lever.

Always move the cam blocks on the opposite side of lever from which you wish to change the stroke.

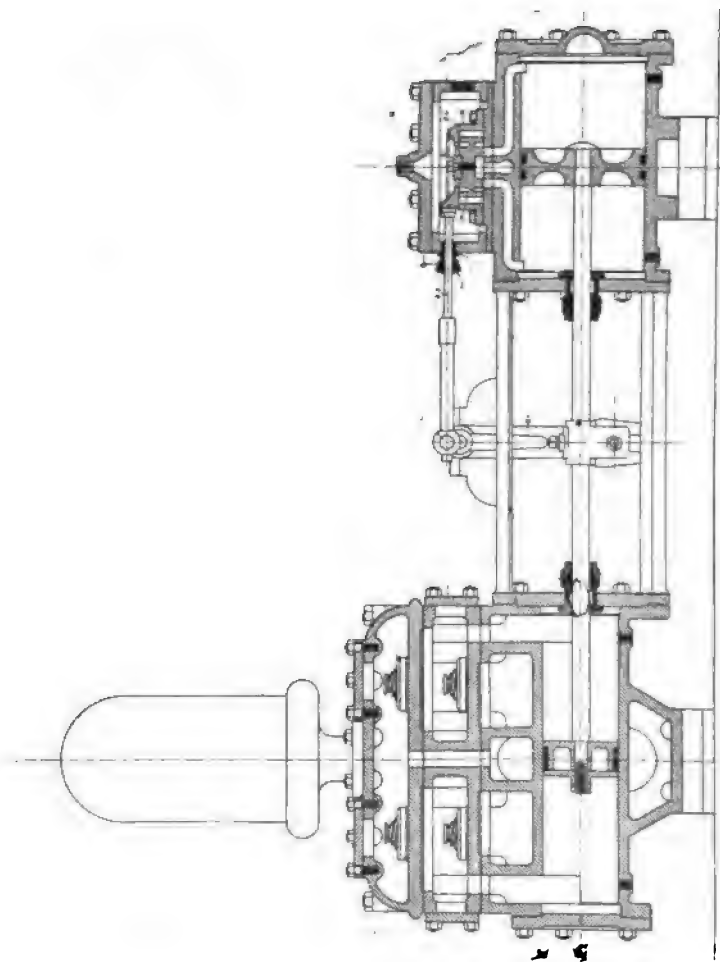
In all cases the piston should make as long a stroke as possible and give the required speed to do the work.

In all pumps made up with cast iron yokes not showing the marks for length of stroke, push the piston to one end until it strikes cylinder head, and scratch a mark on the piston rod at the stuffing box. Repeat this same operation on the other end, and use these marks to adjust the valve as described.

The Blakeslee Direct Acting Steam Pump.—In Fig. 203 is shown this type of a direct steam pump.

The Deane Direct Acting Steam Pump.—In none of the so-called direct acting steam pumps is a rotary motion developed by means of which an eccentric can be made to operate the valve. It is, therefore, necessary to reverse the piston by an impulse derived from itself at the end of each stroke. This cannot be effected in an ordinary single valve engine, as the valve would be moved only to the center of its motion, and then the whole machine would stop. To overcome this difficulty, a small steam piston is provided to move the main valve of the engine.

In the Deane pump, shown in Fig. 204, the lever 90, which is carried by the piston rod, comes in contact with the tappet when near the end of its motion, and, by means of the valve rod 24, moves the small slide valve which operates the supplemental piston 9. The



BLAKESLEE SINGLE
Showing Piston and Connecting Rod

The Blakeslee Direct Acting Steam Pump.

Fig. 203.

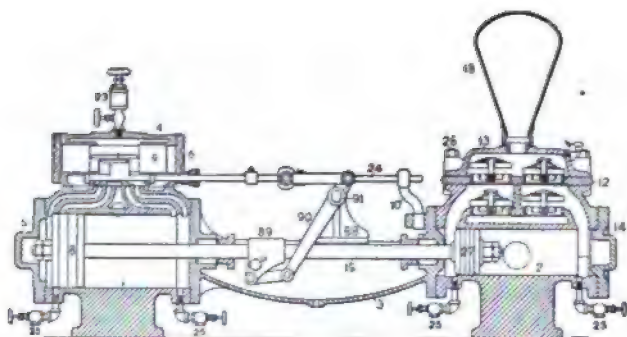
supplemental piston, **carrying with it the main valve**, is thus driven over by steam, and the engine reversed. If, however, the supplemental piston fails accidentally to be moved, or to be moved with sufficient promptness by steam, the lug on the valve rod engages with it and **compels** its motion by power derived from the main engine.

The Hooker Direct Acting Steam Pump.—The essential point in **steam pumps**, is the movement of the **steam valves**, which control the admission and release of the steam to and from the **steam cylinder**, for on this depends the correct and even length of the stroke of **pumps** and economical distribution of steam for the required duty.

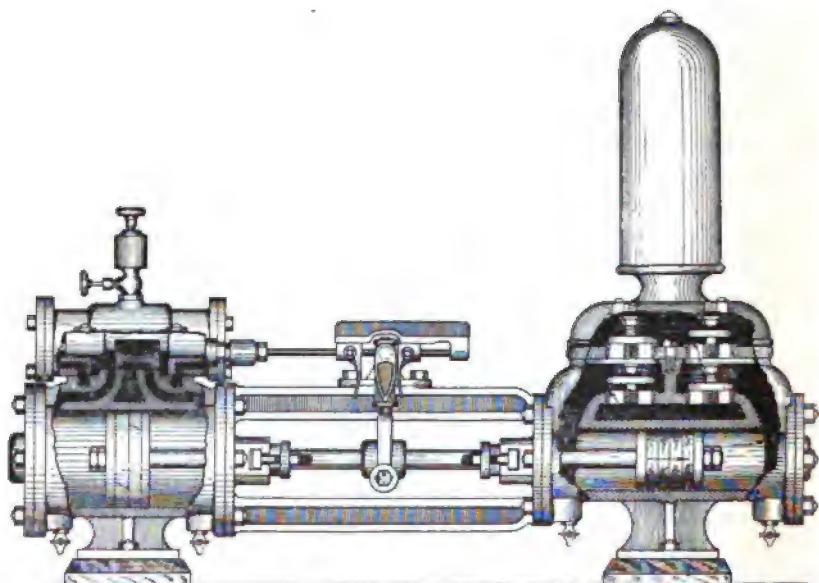
The **accelerated valve movement** in the construction of the Hooker pump, as seen from Fig. 205, produces the desired results, that is, their pistons will always make **full strokes** under any pressure and speed.

The cam which is cast integral with the rock shaft, is always in contact with one wiper on the **valve rod**. The **steam valve** starts slowly, its speed is gradually accelerated to the point of reversal of the piston when the maximum valve travel is attained. This compels the pump to make full and even strokes without resort to tappet connections to move the valve, thereby avoiding all pounding. These pumps will run noiselessly and smoothly at all speeds and pressures. The main **steam valve** is cushioned on compressed live steam; it reverses instantly and without noise or shock.

The Knowles Direct Acting Steam Pump.—The prime advantage of this pump, shown in Fig. 206, is its absolute freedom from what is termed a "**dead center**." This feature is secured by a very simple and ingenious mechanical arrangement, i. e., by the use of an auxiliary



The Deane Direct Acting Steam Pump.
Fig. 204.



The Hooker Direct Acting Steam Pump.
Fig. 205.

piston which works in the steam chest and drives the main valve. This auxiliary or "chest piston," as it is called, is driven backward and forward by the pressure of steam, carrying with it the main valve, which valve, in turn, gives steam to the main steam piston that operates the pump. This main valve is a plain slide valve of the B form, working on a flat seat.

The chest piston is slightly rotated by the valve motion; this rotative movement places the small steam ports (which are located in the under side of the said chest piston) in proper contact with corresponding ports cut in the steam chest. The steam entering through the port at one end and filling the space between the chest piston and the head, drives the said piston to the end of its stroke and, as before mentioned, carries the main slide valve with it. When the chest piston has traveled a certain distance, a port on the opposite end is uncovered and steam there enters, stopping its further travel by giving it the necessary cushion. In other words, when the rotative motion is given to the auxiliary or valve driving piston by the mechanism outside, it opens the port to steam admission on one end, and at the same time opens the port on the other end to the exhaust. Thus instant and **positive** motion is secured with but few working parts. There is no point in the stroke at which either the chest piston or the main piston is not open to direct steam pressure. Hence the immunity from any dead point whatsoever.

Operation.—The piston rod, with its tappet arm, moves backward and forward from the impulse given by the steam piston. At the lower part of this tappet arm is attached a stud or bolt on which there is a friction roller. This friction roller, with its bolt and nut, can be lowered or raised, when it is desired, to adjust

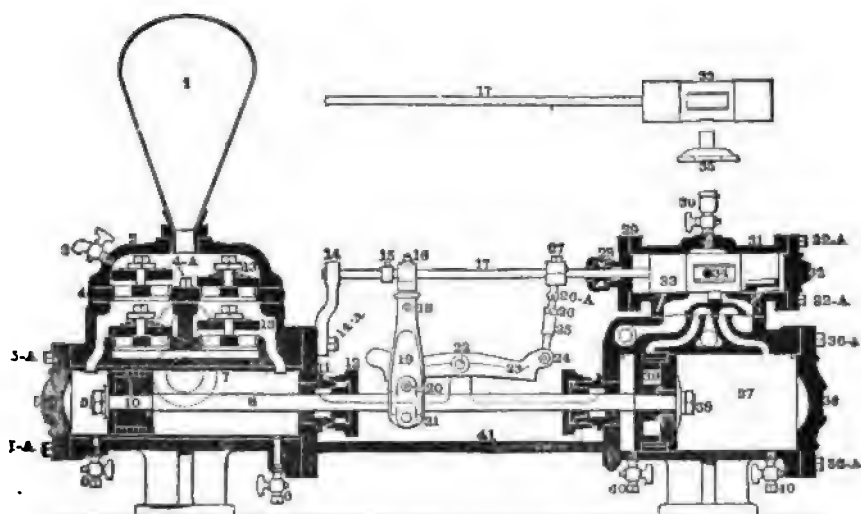
the pump for a longer or shorter stroke. This roller, coming in contact with the "rocker bar" at the end of each stroke, operates the latter. The motion given the "rocker bar" is transmitted to the valve rod by means of the connection between, causing the valve rod to partially rotate. This action, as mentioned above, operates the chest piston, which carries with it the main slide valve. The said valve giving steam to the main piston, the operation of the pump is complete and continuous. The upper end of the tappet arm does not come in contact with the tappets on the valve rod, except the steam pressure from any cause should fail to move the chest piston, in which case the tappet arm moves it mechanically. This makes the pump absolutely positive.

Directions.—Should a pump run longer stroke one way than the other, simply lengthen or shorten the rocker connection (Part 25) so that rocker bar (Part 23) will touch rocker roller (20) equally distant from center (22).

2. Should a pump hesitate in making its return stroke, it is because rocker roller (20) is too low and does not come in contact with the rocker bar (23) soon enough. To raise it, take out rocker roller stud (20-A), give the set screw in this stud a sufficient downward turn, and the stud with its roller may at once be raised to proper height.

3. Should valve rod (17) ever have a tendency to tremble, slightly tighten up the valve rod stuffing box nut (28). When the valve motion is properly adjusted, tappet tip (16) should not quite touch collar (15) and clamp (27). Rocker roller (20), coming in contact with rocker bar (23) will reverse the stroke.

4. The water piston is adjustable by means of segments that can be seen by taking off the follower, and



The Knowles Direct Acting Steam Pump.
Fig. 206.

the packing quickly set out to always insure perfect suction and at the same time not be so tight as to bind.

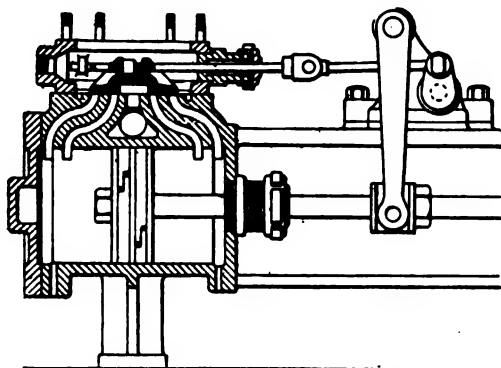
Construction of Duplex Steam Pumps.—In Fig. 211 is shown a sectional view of the ordinary construction of a duplex steam pump.

The Worthington Duplex Steam Pump.—In Fig. 214 is shown an outside view of this pump. The steam valve, as may be seen at E, Fig. 211, is an ordinary **slide valve**, which is the simplest and most reliable valve known to engineers.

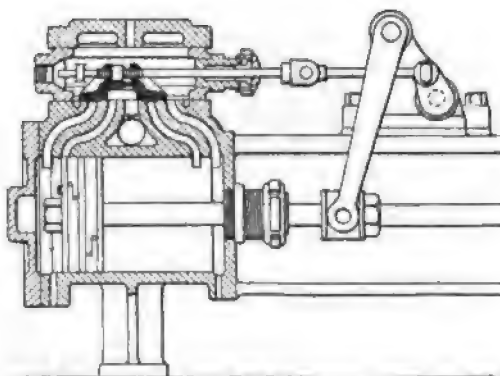
In the Worthington pump the motion of this valve is controlled by a vibrating arm, seen at F, Fig. 211, which swings through the whole length of the stroke. As the moving parts are always in contact, the blow inseparable from the tappet system is avoided.

This valve motion is the prominent and distinguishing characteristic of this pump. Two steam pumps are placed side by side and so combined that one piston acts to give steam to the other, after which it finishes its own stroke and waits for its valve to be acted upon by the other pump before it can renew its motion. This pause allows the water valves to seat quietly, and removes any harshness of motion. As one or the other of the steam valves is always open, there is no dead point, and therefore the pump is always ready to start when the steam is admitted. The same type of steam cylinder and valve motion is furnished with pumps of either the plunger-and-ring pattern or the piston pattern.

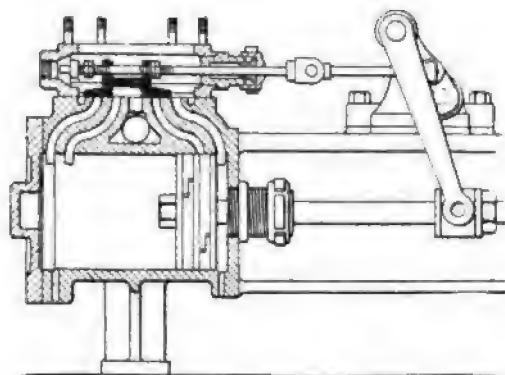
In the plunger-and-ring pattern there is a double acting plunger working through a deep metallic ring bored to fit accurately the plunger. The plunger is located some inches above the suction valves, leaving a subsiding chamber, into which any foreign substance may fall out of the way of the wearing surfaces. Both



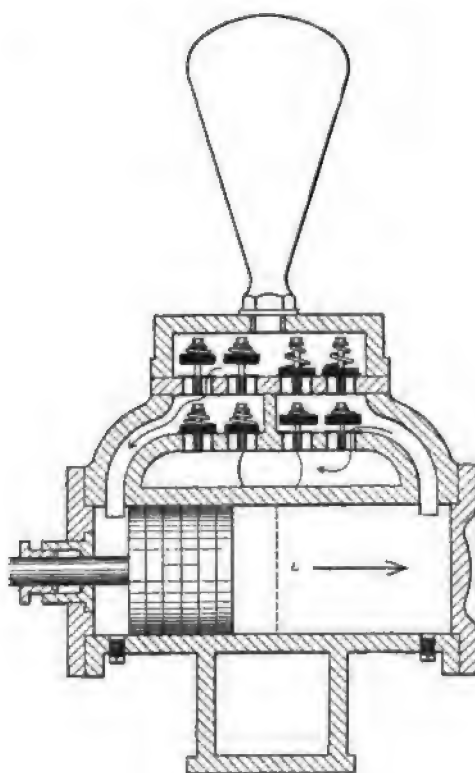
Position of the Gear when setting Valves of Duplex Pump.
Fig. 207.



Proper Position of the Valve at commencement of the Stroke.
Fig. 208.



Method of Cushioning the Steam Piston of a Pump.
Fig. 209.



Water End of Steam Pump, Showing Lift of Valves.
Fig. 210.

the plunger and ring can be quickly taken out and either refitted or, when necessary, renewed at small cost. The valves consist of small discs of rubber, or other suitable material, and are easily accessible through convenient hand-holes.

In the piston pattern pump there is a packed water piston, working in a brass lined cylinder. Both the suction and the discharge valves are located above the water pistons, so that the pistons may be at all times submerged. The valve areas and water passages are large, and special care is taken to have all the internal parts easily accessible for inspection and repairs. This pattern is recommended where the liquid to be pumped contains small quantities of grit or foreign material, or where there is an unusually long or high suction lift. In both arrangements all the moving parts are made to gauge, and may be readily removed.

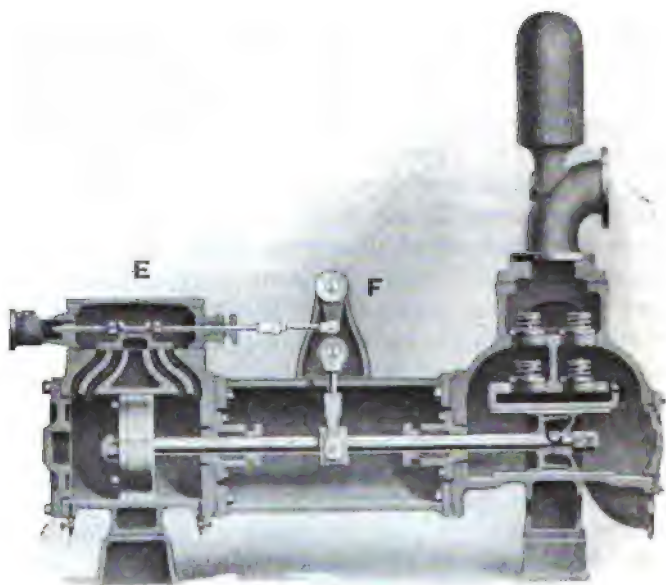
In Fig. 212 is shown an exterior view of the ordinary type of a duplex pump.

The Snow Duplex Steam Pump.—The sectional view, shown in Fig. 213, serves to illustrate the extreme simplicity of the Snow steam pump. These pumps are of the duplex pattern, consisting of two direct acting engines and two double acting pumps, so coupled that the steam piston of one actuates, through the medium of the vertical lever, the steam distribution valve of the other.

The advantages of the Snow duplex valve motion are as follows:

1st. It is so simple that its operation can be understood by anybody, whether a mechanic or not.

2d. It is reliable, and will continue to distribute the steam and operate the pump under even the most extreme conditions of wear and abuse.



Sectional View of a Duplex Steam Pump.

Fig. 211.

3d. It can never place the valves in such a position that all the ports are covered by them at the same time; hence, the pump can always be started by simply turning on steam, and it can never stall.

Explanation.—Assume that the pistons of No. 1 side have completed the stroke. They have then moved the slide valve of No. 2 side to one extreme position and opened full the admission port to one end and the exhaust port from the other end of No. 2 cylinder; hence the No. 2 pistons are making their stroke and are gradually reversing the slide valve of No. 1 side. When the No. 2 pistons have completed about two-thirds of their stroke, they have moved the slide valve of No. 1 side so that it has just begun to open the No. 1 ports, to start the No. 1 pistons on their return stroke. No. 2 pistons continue to move to complete the stroke, and to open the No. 1 ports, and by the time they have completed about five-sixths of their stroke the No. 1 pistons have gotten under way on their return stroke, and the No. 2 steam piston has covered the exhaust port through which steam was being exhausted and is slowing down under the influence of the cushion or dash relief valve. This valve intercepts a small port connecting the steam port with the exhaust port at each end of each steam cylinder, and through which the imprisoned exhaust steam has to pass to permit the pistons to complete their stroke. This they do, gradually slowing down and finally coming to rest at the end of the stroke, having moved the slide valve of No. 1 side to its extreme position, thus opening the No. 1 ports wide. By this time the No. 1 pistons have completed about one-half of their stroke and are reversing the slide valve of No. 2 side, while the No. 2 pistons are at rest; and when the No. 1 pistons



A Type of a Duplex Steam Pump.
Fig. 212.

have completed about five-sixths of their stroke, and are slowing down under the influence of the cushion valve, the No. 2 pistons are under way again on their return stroke, while the No. 1 pistons gradually slow down and come to rest at the end of their stroke.

The effect of the slowing down and the pause at the end of the stroke can be readily seen from the following: While the pump piston, or plunger, is moving at its highest velocity, the suction valves on one end and the delivery valves on the other end are raised to the highest position from their seats; but while the piston, or plunger, slows down and pauses at the end of the stroke, they seat gently, so that by the time the return stroke is begun the valves have seated and the opening of the other valve is cushioned by the valve springs.

The result is the entire absence of valve hammer, so common in quick reversal pumps.

It causes the pump to deliver a steady and uniform flow of water, thus preventing any water hammer in the pumps or pipes.

THE PARTS OF THE SNOW PISTON PATTERN STEAM PUMP

1 Steam Cylinder	28 Rock Shaft Key or Pin	61 Valve Plate
6 Drain Cocks	29 Steam Piston Body	62 Air and Drain Cocks
8 Steam Cylinder Head	33 Steam Piston Ring	63 Piston Pump Cylinder Head
9 Foot	34 Steam Piston Nut	65 Pump Piston Body
10 Steam Chest	35 Piston Rod	66 Pump Piston Follower
11 Steam Chest Cover	36 Piston Rod Stuffing Box	75 Driven Lining
14 Side Valve	37 Piston Rod Gland	
15 Valve Rod Nut	37½ Piston Rod Stuffing Box Follower	
16 Valve Rod	38 Spool and Pin	
17 Valve Rod Gland	42 Pump Piston Nut	
17½ Valve Rod Stuffing Box Follower	45 Pump Cylinder	
18 Valve Rod Head	47 Valve Seat	
19 Valve Rod Head Pin	48 Pump Valve	
20 Long Valve Rod Link	49 Valve Guard	
20½ Short Valve Rod Link	50 Valve Spring	
21 Crank Pin	51 Valve Washer	
23 Cross Stand	56 Force Chamber	
24 Upper Rock Shaft	60 Air Chamber	
25 Lower Rock Shaft		
26 Long Valve Motion Lever		
27 Short Valve Motion Lever		

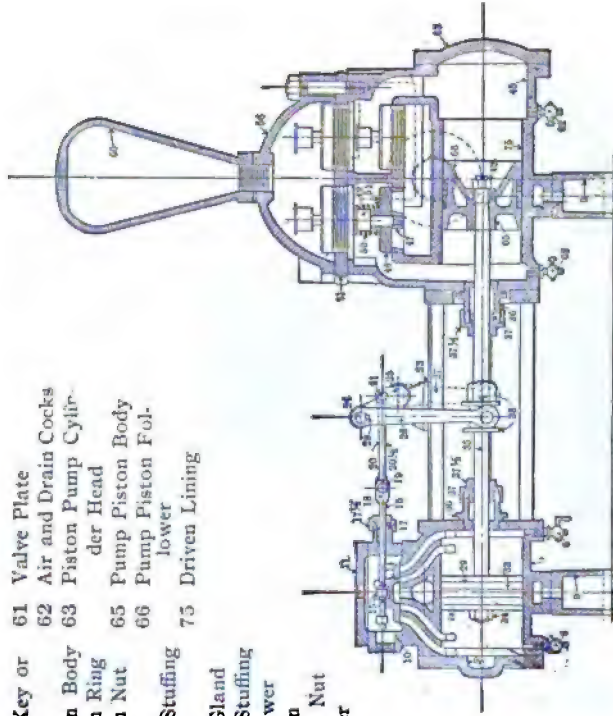


Fig. 213.

CHAPTER XXIII.

QUESTIONS AND ANSWERS ON PUMPS.

Q. What is a pump?

A. A mechanical device for transferring or circulating fluids.

Q. What are the two common methods of operating pumps, and how designated?

A. By direct connection with the steam cylinder, called direct acting pumps; by belting or gearing, called belted pumps.

Q. How are boiler feed pumps usually operated?

A. By direct connection to steam cylinder, that is, by direct acting steam pumps.

Q. How is the water piston mounted in a direct acting pump?

A. On the same rod as the steam piston.

Q. How is a single direct acting pump carried over the dead center?

A. By an auxiliary valve gear in connection with the main valve gear.

Q. Is a duplex pump a direct acting pump?

A. Yes.

Q. Is a single cylinder pump a direct acting pump?

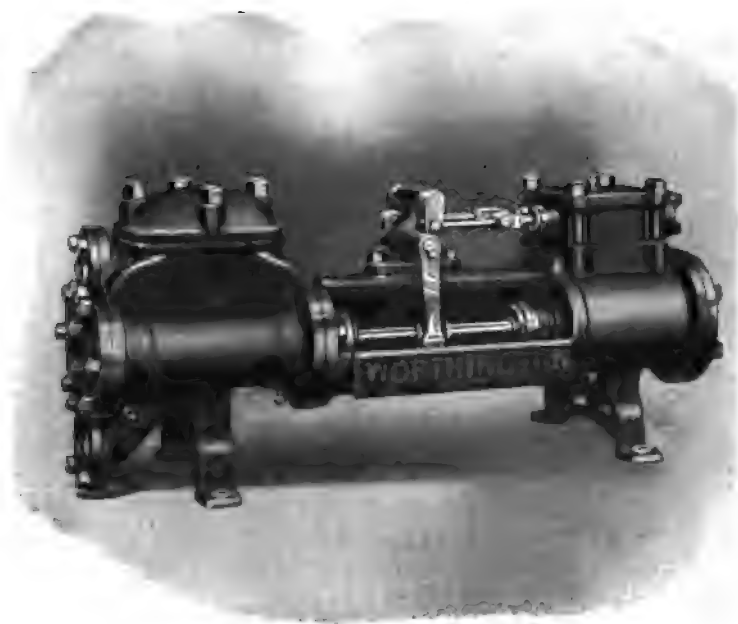
A. Yes, it differing chiefly from a **duplex** pump in the operation of its valve gear.

Q. How many valves has a single acting plunger pump?

A. Two valves, one for receiving and the other for discharging.

Q. How many valves has the double acting pump?

A. Four valves, two for receiving and two for discharging.



The Worthington Duplex Steam Pump.
Fig. 214.

Q. How many valves do large pumps often have on the water cylinder?

A. They often have as many as sixteen and frequently thirty-two small valves on the water cylinder.

Q. Would it not be better to have a few **large** valves instead of so many **small** valves on this cylinder?

A. No, because the small valves do not require as much **lift** as the larger ones, consequently at each stroke of the pump they do not lose the quantity of water that would be lost with the larger valves.

Q. Which should have a larger area, the steam piston or the water piston of a pump?

A. The steam piston, otherwise the pressure on the water piston would **equal** the pressure on the steam piston and the pump would refuse to work.

Q. How much larger area should the steam piston have than the water piston?

A. About two and three-fourths times the area of the water piston.

Q. How would you therefore find the area of the steam piston?

A. Multiply the area of the water piston by 2.75.

Q. How do you find the **horse power** necessary to pump water to a given height?

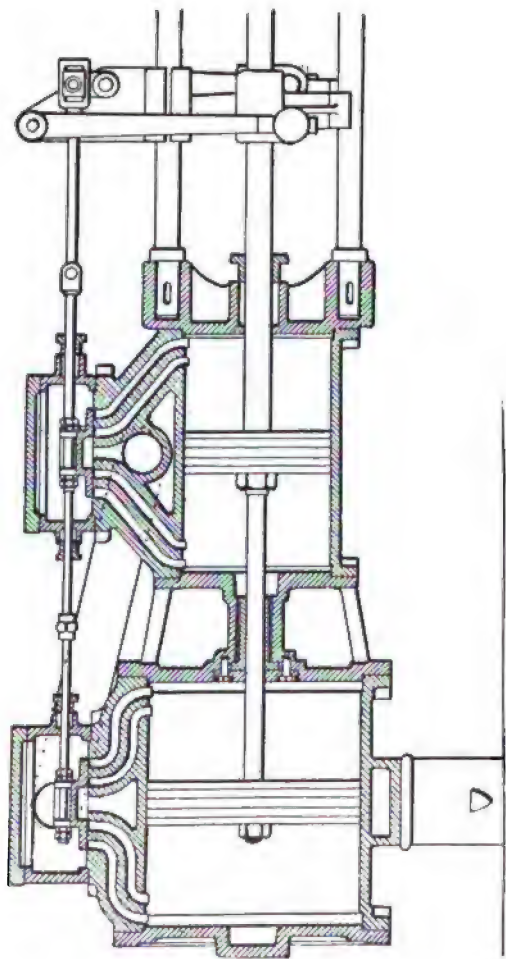
A. Multiply the total weight of the water in pounds by the height in feet, and divide the product by 33,000.

Q. How do you find the **pressure** in pounds per square inch of a column of water?

A. Multiply the height of the column in **feet** by .434.

Q. At what piston speed should an ordinary boiler feed pump be run?

A. About fifty or sixty feet per minute.



Sectional View of a Compound Duplex Steam Pump.
Fig. 215.

Q. What are the disadvantages of fly wheel pumps?

A. Their great weight, and their inability to be run slowly.

Q. Why are the valves of duplex pumps made without lap?

A. In order to avoid the danger of sticking upon the centers.

Q. What precautions should be taken in leaving pumps in cold weather?

A. All the water should be drained in order to avoid freezing. Therefore, the drip plugs and cocks which are provided for the purpose of draining the pump, should be **opened**.

Q. How would you choose the proper size of a boiler feed pump for a given boiler?

A. Multiply the horse power of the boiler by $34\frac{1}{2}$, which will give the number of **pounds** of water evaporated by the boiler per hour from and at 212 degrees. Divide this result by 8.35, which gives the number of gallons. Then choose a pump capable of supplying **double** this quantity, so that it will be large enough even when the boiler is being **forced** to its utmost.

Q. How do you designate the size of a pump?

A. By giving the diameter in inches of the steam end, by that of the water end, by the length of the stroke, in the order named.

Q. Give an example?

A. A pump 8"x6"x10," is a pump having an 8-inch steam end, 6-inch water end and a 10-inch stroke.

CHAPTER XXIV.

ELECTRICITY AND MAGNETISM.

Definition.—What is electricity is not known. It is invisible and impalpable. Our knowledge of it is confined to its **generation** and application, but that alone is of the greatest moment to the engineer and student, for without such knowledge no stationary engineer should hold a first-class license, permitting him to operate a modern steam plant.

Electricity is now so universally used, that in addition to the many growing demands upon the modern steam engineer, is the necessity for a thorough knowledge of the operation of electrical generators and motors, and a thorough understanding of the **principles** upon which they operate.

Electricity.—The name **electricity** is derived from the Greek word **electron**, which means **amber**. It was discovered many centuries ago, that amber when **rubbed** possessed the curious property of attracting light bodies. This manifestation of attraction in the amber or **electron**, was believed by the Greek: to be due to a spirit that dwelt within the amber, and which was aroused by the warmth generated by the friction of the rubbing.

Such was the discovery of the wonderfully subtle force that is revolutionizing the world, and which requires every student or engineer who hopes to make success in any branch of the engineering field to master its principles and operation in order to succeed in his particular work.

Static Electricity.—This is a term employed to designate electricity produced by **friction**. When static electricity is discharged, it produces more or less a current which shows itself by the passage of a spark, but

is only of short duration, and is of no practical value. It is electricity **at rest**, and is used in distinction to electricity **in motion**, or **dynamic** electricity, which is of far more importance, and which will therefore be chiefly considered in this work.

Classification.—The subject of electricity is divided into the following classes, viz.:

- (1) Static electricity, or electricity **at rest**.
- (2) Current electricity, or electricity **in motion**.
- (3) Magnetism, or electricity **in rotation**.
- (4) Electricity in vibration or **radiation**.

Generation.—The usual method of generating static electricity, is by the use of what is known as the **plate machine**.

Plate Machine.—This machine consists of a circular plate of glass that is mounted upon a shaft made to turn by means of a crank and handle. Pressed to either side of the glass, at the top and bottom, is a rubber made of cloth, felt or soft leather.

At right angles to the rubbers on the circle of the plate, there is a frame from which a number of sharp points project which are brought so that they almost touch the plate. These points and the frame to which they are attached, are connected by a good conductor to what is known as the prime conductor.

Operation.—The operation of such a machine is exceedingly simple. The plate is caused to revolve, and the **frictional** action of the rubbers upon it, charges it with electricity. As the successive portions of the glass plate pass beneath the points, the electrical charge is drawn off and carried by them to the prime conductor, from which it can be drawn in turn to the Leyden jar wherein it is stored.

• **Current or Dynamic Electricity.**—Current electricity

may be defined as a quantity of electricity which passes through a conductor, or is electricity in **motion**. The production of **all** electricity is the transforming of one form of energy into another, usually by mechanical means; and in this form of electricity, the device for effecting such transformation of **mechanical** into **electrical** energy, is called a **generator** or **dynamo**.

An electrical motor, on the contrary, is a device for changing **electrical** into **mechanical** energy.

Manifestations.—An electric current manifests itself by the **heating** of the wire or the conductor through which it passes, or, by causing a **magnetic field** around the wire or conductor, or lastly, by causing **chemical changes** in a liquid through which it is made to pass.

All these manifestations indicate the character of useful work capable of being performed by an electric current. First, the **heat** caused by the resistance of the conductor through which the current passes, is made to generate light and heat. Second, the **magnetic field** around the wire or conductor is used to operate all character of electrical machines and motors and also make high voltage currents safe and practical by the use of transformers. Third, the **chemical changes** brought about in the liquid by the passage through it of the current, is used for the storage of electricity to be later used, as needed.

Primary Batteries.—The simplest method of generating electricity for practical use, is by an electrical battery.

Principle.—If a plate of metal is placed in a liquid called an **electrolyte**, there is set up a chemical action which produces **different** conditions of energy between the metal and the liquid, and the metal either takes a lower or a higher electrical potential than the liquid in

which it is immersed, according to the nature of the metal and the liquid.

Cell.—Now, if **two** different metals or elements are placed in the electrolyte, there is a **difference** of potential or energy at once produced between these two plates or elements, and if we should join them by a wire outside of the electrolyte or liquid, a current of electricity would pass over this wire from the metal most acted upon by the electrolyte to the one least acted upon by it.

The two metals or elements and the electrolyte compose what is known as a **simple electrical cell**, and such an apparatus for developing a continuous current of electricity, is named from its discoverers, a simple voltaic or galvanic cell.

Such a cell consists essentially of a vessel containing saline or acidulated water in which are submerged two plates of **dis-similar** metals, or one metal and a metalloid.

Action of a Simple Cell.—The action of a simple electrical cell is as follows: If in a glass jar partly filled with water, a little sulphuric or other dilute acid is added, and a clean strip of zinc and one of copper is placed, a chemical action will at once set up from the action of the acid on the zinc plate, producing a difference of electrical potential between the two plates, causing the current to flow from the one of higher potential to the one of less potential. If now the two electrodes are connected by a wire, there will be a **continuous** flow of electric current from the submerged end of the zinc plate through the liquid to the submerged end of the copper plate, and from the exposed end of the copper plate through the wire to the exposed end of the zinc plate.

Chemical Reaction.—The chemical reaction which

occurs is represented as follows: $\text{Zn} + \text{H}_2 \cdot \text{SO}_4 = \text{ZnSO}_4 + \text{H}_2$.

Which is equivalent to saying that the zinc (Zn) combining with the sulphuric acid ($\text{H}_2 \text{SO}_4$) produces zinc sulphate (ZnSO_4) and free hydrogen gas, (H_2). The hydrogen is given off as a gas from the liquid, leaving the zinc sulphate in solution. This action continues as long as the current flows, which depends upon the **amount** of current flowing. The zinc gradually dissolves in the liquid, forming a solution of zinc sulphate. This chemical action **ceases** when the liquid no longer contains any **acid**, or when the zinc has been **exhausted**. The spent liquid must then be replaced with a new acid solution, and a new piece of zinc substituted.

Polarization.—One great objection to the simple voltaic cell, is that the current produced rapidly decreases in strength after the circuit has been closed for a short time. This is due to the collection of hydrogen bubbles upon the surface of the copper plate, which **prevent** the direct contact of the copper plate with the exciting fluid, and in this way the **effective area** of the plate is reduced, and proportionately, the strength of the current. This also greatly increases the **internal resistance** of the battery, thus decreasing the flow of the current.

This accumulation of hydrogen bubbles is called **polarization**, and the cell is said to become **polarized**.

Depolarization.—This consists of **reducing** or **removing** the polarization of a voltaic cell or battery. This is done by replacing the **single** fluid cells with **double** fluid cells. In this way the inactive plates about which the bubbles would otherwise collect, is placed in a liquid which chemically **unites** with the hydrogen, thus removing same.

Current.—The electrical current produced is a continuous current, but of low voltage or pressure, and capable of doing but little useful work.

Battery.—To **increase** the strength of the current, **several** of these cells are joined together and are then called a **battery**. The strength of the battery is almost exactly proportional to the number of cells or elements of which it is composed.

These different cells can be connected together in three different ways in forming a battery; (1) by the **series** method, as shown in Fig. 236; (2) by the **parallel** or multiple **arc** method, also shown in Fig. 236, or, (3) in **multiple-series** method.

Series.—Cells are connected in **series** when the positive electrode of one cell is connected to the negative electrode of the second cell, and the positive electrode of the second cell is connected to the negative electrode of the third cell; continuing in this way for all the cells of the battery.

Parallel.—Cells are connected in parallel, or multiple-arc, when all the positive electrodes of the cells are connected to one main **positive** conductor, and all the negative electrodes are connected to one main **negative** conductor.

Multiple-Series.—Cells are connected in multiple-series when arranged in several groups, each group being composed of several cells connected in **series**, and then all the groups being connected in **parallel**, or multiple-arc.

While the **quantity** of the electricity which is generated is the same in each of the methods of connecting the cells, the **effects** resulting therefrom are quite different.

The series connection gives a **high** electrical pres-

sure or voltage, and a **small** volume of current, or amperage; while the parallel connection gives a **low** electrical pressure or voltage, and a **large** volume of current, or amperage.

The combination of these two methods of connecting cells, that is the multiple-series, gives a **higher** potential and a **stronger** current than is possible to obtain from any one cell of the groups of cells.

Construction of Cells.—Instead of using copper and zinc, other dis-similar substances can be used to produce an electrical current, and instead of using one electrolyte, two or more different electrolytes can be used. In this way a number of different cells for producing different electrical currents are constructed, each adapted to its special class of work.

In order to understand the action of an electrical current and its effects, the following **definitions** of the terms used in electrical work must be first fully understood.

Positive and Negative.—An electric charge developed upon glass by rubbing it with silk, has been termed for convenience a **positive** (+) charge, and that developed on resinous bodies by rubbing with flannel or fur, a **negative** (—) charge. By the word resinous, we mean electrofication produced in resin by friction.

All electrical charges have **both** a negative and a positive charge in them, irrespective of the way the charge is produced. Electrified bodies with **similar charges** are repelled by each other, while electrofied bodies with **dissimilar** charges are attracted by each other. Therefore, when two positive or two negative charges are brought together, they **repell** each other, but when a positive and negative charge are brought together, they **attract** each other.

Electric Series.—The following substances are arranged in such order that each receives a positive charge when rubbed or placed in contact with any of the bodies following it, and a **negative** charge when rubbed with any of those which precede it.

- | | |
|--------------|------------------|
| 1. Fur. | 9. Wood. |
| 2. Flannel. | 10. Metals. |
| 3. Ivory. | 11. Sealing-wax. |
| 4. Crystals. | 12. Resins. |
| 5. Glass. | 13. Sulphur. |
| 6. Cotton. | 14. Guttapercha. |
| 7. Silk. | 15. Guncotton. |
| 8. The body. | |

For instance, resins when rubbed with **fur** receives a negative charge, but when rubbed with **sulphur** receives a **positive** charge.

Electrodes.—These are the plates of metal or other substance immersed in the liquid. The zinc plate is called a **generating** electrode, and the other plate the **conducting** electrode. In the simple cell thus described, the zinc plate forms the **positive** element of the cell, while the copper plate becomes the **negative** element.

Poles.—The poles of a battery are the parts of the electrodes which project out of the liquid. They are distinguished from each other by the sign (+) for the positive, and (—) for the negative. The term pole, or **terminal** as it is often called, applies to the ends in any electric circuit.

Electrolyte.—The electrolyte, or exciting fluid, is the liquid which acts upon the plates or electrodes placed in it, and produces a current between the two plates and the wire joining them.

Electromotive Series.—The following list of elements compose what is called the **electromotive series**.

- | | |
|-------------|---------------|
| 1. Zinc. | 8. Antimony. |
| 2. Cadmium. | 9. Copper. |
| 3. Tin. | 10. Silver. |
| 4. Lead. | 11. Gold. |
| 5. Iron. | 12. Platinum. |
| 6. Nickel. | 13. Graphite. |
| 7. Bismuth. | |

Any two of these metals produce a difference of potential when submerged in saline or acidulated water, the one standing first on the list being the **positive** element or plate and the other the **negative**.

Classes.—Batteries are divided into two classes according to the nature of work required to be done and the electricity produced, being viz.: (1) **open** circuit batteries; (2) **closed** circuit batteries.

Open-Circuit Battery.—This battery is so constructed as to maintain a current that will not run down or exhaust itself when left on an open circuit

This is the most common form of battery, being used for telephones, electric bells, annunciators, etc.

Leclanche Cell.—This is a typical **open** circuit cell, and is constructed as follows.

Construction.—A rod of zinc forms the positive element. The negative element is contained in a **separate** jar of porous earthenware, and consists of a rod of carbon surrounded with powdered carbon and peroxide of manganese. The cell is almost filled with a solution of sal-ammoniac and water.

Upon closing the circuit outside the cell, the zinc combines with the chlorine and the sal-ammoniac, and liberates hydrogen gas and ammonia.

Hydrogen also appears at the carbon plate, the peroxide of manganese giving off its oxygen to combine with the hydrogen to form water, H_2O . In this way the **depolarizing** takes place when the cell is not discharged through too low a resistance.

Should a **Lachance** cell be worked too rapidly, it must then be allowed to **rest** so as to permit the manganese time to work, and the cell to be thus recuperated.

The E. M. F. of a Lachance cell is about 1.45 volts, while its current varies from one ampere upwards, according to the resistance of the cell.

The resistance may be decreased by using a sheet of zinc bent around the porous pot, or by making the negative element in a compressed form, so as to dispense with the use of a porous pot.

The Daniell Cell.—This is a typical **closed circuit** cell, and is usually called a gravity cell, or a gravity Daniell cell, owing to the principle upon which it operates, being the difference of the **weight** in the two electrolytic liquids.

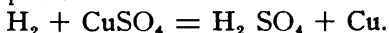
Construction.—A number of thin leaves of copper are placed in the bottom of a jar, and sulphate of copper crystal poured over them.

A zinc block is hung from the top of the jar, so as to leave a space of a few inches between it and the copper.

Water is then poured in the jar with a little sulphate of zinc, or a few drops of sulphuric acid, to hasten the action.

The action of the cell rests upon the sulphate of copper liberating its sulphuric acid, which is deposited as copper on the copper plate. The sulphuric acid thus liberated attacks the zinc, forming zinc sulphate, the porous cup protects the zinc from the copper sulphate solution, and this solution prevents the hydrogen from

accumulating about the copper. The hydrogen unites chemically with the copper sulphate, forming sulphuric acid and free copper. The free copper is then deposited upon the outside copper portion. The chemical reaction is represented as follows:



This cell is much used in telegraphy being very constant in its action, as no polarization can take place as long as the copper sulphate solution is **saturated**.

It is called a **gravity** cell owing to the copper sulphate solution remaining at the bottom of the jar, and the zinc sulphate solution at the top, the line of division being strongly marked.

The E. M. F. of a gravity Daniell's cell is about one volt, its current flow being from one to two amperes.

Primary and Secondary Cells.—A **primary** cell as seen above, is one in which the electric energy is produced by the chemical action on the plates of the cell, and which, when the solutions or plates are exhausted, are **not** restored to their original condition by the passage of an electric current. Almost all primary cells will act more or less perfectly as secondary or storage cells.

Circuit.—A circuit is a path composed of a conductor, which is usually copper wire, through which an electric current flows from a given point around through the conductor back again to the starting point. There is no **actual** flow of the current, for there is no transfer of matter or particles. A conductor carrying a current presents the same appearance as one not, the only manifestation being the heating of the conductor, should the capacity of the wire be too small for the current carried. The flow of the current is caused by the difference of potential, and the greater the amount of potential dif-

ference, the greater is said to be the **pressure or electromotive force**, usually written E. M. F., or voltage which causes the flow. The **strength** of the current flowing through the conductor depends directly upon the amount of this electromotive force, and also upon the amount of the resistance to the flow. If the circuit is short and composed of good conductors, the current will be much stronger than if it were long and composed of poor conductors.

Grounded Circuit.—A circuit in which the earth, or ground, forms part of the circuit is called a **grounded circuit**.

External Circuit.—The **external** circuit is that part of a circuit which is **outside** or external to the generator or other source of supply.

Internal Circuit.—The **internal** circuit is that part of a circuit which is included or within the generator, or other source of supply.

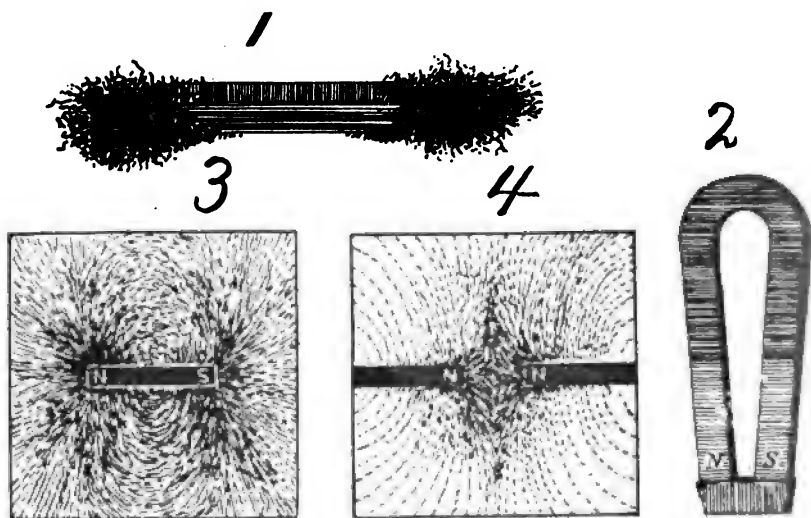
Magnetism.—Substances which have the property of attracting pieces of iron or steel are called **magnets**. A material possessing this property was first found at Magnesia, in Asia Minor, which fact led to all substances possessing this property being called **magnets**.

Natural Magnets.—The natural magnet is an oxide of iron, called **lodestone**, and is found widely distributed in different parts of the world.

Artificial Magnets.—When a bar of hard steel is rubbed with a lodestone, the steel will acquire some of the properties of the magnet, and can be used as a magnet as long as it retains those properties.

When such magnets retain their magnetism for a long time, they are then called **permanent** magnets.

In Fig. 216 (2) is shown a common form of a permanent magnet. It consists of a bar of steel bent into



1. Poles of Magnet. 2. Horse Shoe Magnet. 3. Magnetic Field.
4. Opposing Magnetic Field.

Fig. 216.

the shape of a horse shoe, and then hardened and magnetized. A piece of soft iron, called an **armature**, is placed across the two ends of the horse shoe which assists in preventing the steel from losing its magnetism.

This is only one of the many forms into which a permanent magnet may be made.

In the Fig. 216 (1) is shown a **bar magnet** which has been dipped into iron fillings. It will be noticed that the fillings cling to it in great numbers at the **two ends** of the bar, but there are but few attracted to the **middle** of the bar. The ends of the magnet where the attraction is the greatest, are called the **poles**, and the part of the magnet where there is no apparent magnetic attraction, is called the **neutral zone**.

An imaginary line shown through the center of the magnet from one end to the other end, connecting the two poles, is called the **axis of magnetism**.

Compass.—The most common example of a magnet is the **compass** needle. Such a needle, or magnet, always places itself so as to point north and south, and the same pole always points to the north and the other to the south. The end which points north, is called the **North Pole**, and the other the **South Pole**.

If the north poles, or south poles, of two such compass needles be brought near each other, they will be repelled, but when the north pole of one needle is brought near the south pole of the other, they will **attract** each other. This demonstrates what has been hertofore stated, viz.: that **like** poles **repel**, and **unlike** poles **attract** each other. The **earth** is the magnet which makes the compass always point north and south, that is towards the **magnetic** poles of the earth, which poles nearly coincide with the geographical north and south pole of the earth.

A magnet always had two poles, however **minute** the particles into which it may be broken, and these poles always possess the same magnetic properties.

Magnetic Field.—The space surrounding a magnet in which a magnetic substance will be attracted, or repelled by it, is called the **magnetic field**.

In Fig 216 (3) is shown the magnetic field surrounding a bar magnet, which can be seen by placing a sheet of paper upon such a magnet, and spreading iron filings evenly over the paper. By tapping the paper lightly the filings will form themselves into a series of **curved lines** extending from one pole of the magnet to the other.

This can be repeatedly tried with different magnets and under different conditions, and it will be found that the filings will always form themselves into these well defined curves extending from one pole to the other.

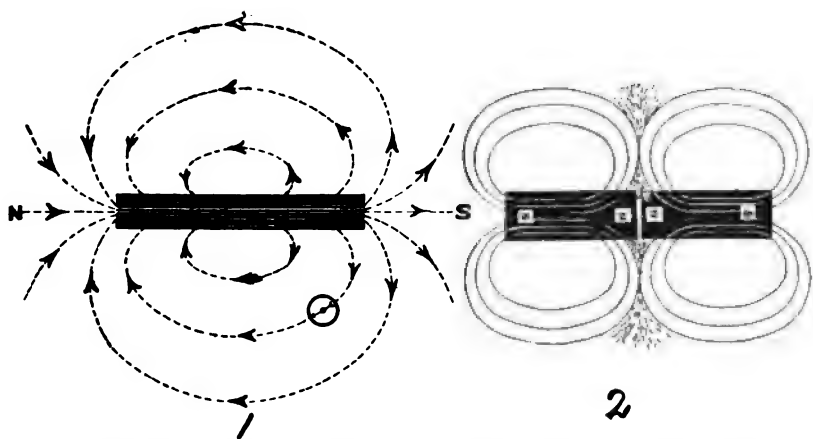
These lines are called **lines of force**, or lines of **magnetic force**.

Lines of Force.—The formation of these definite and well defined lines indicates that the magnetic field exerts its influence always in certain fixed directions.

Should two **like** poles, as shown in Fig. 216, (4) be brought near each other, then their repellant forces can be clearly seen from the direction of the lines of force, which tend to move away from each other. This is also shown in Fig. 217 (2).

All lines of force are assumed to pass out from the **north pole**, make a complete circuit through the surrounding medium, re-entering the magnet through the **south pole**, and thence pass through the magnet to the north pole again.

These lines of force during their entire circuit are shown in Fig. 217 (1), and also the circuit of the lines



1. Directions of Lines of Force. 2. Opposing Lines of Force.
Fig. 217.

of force when the **like** poles of two magnets are brought near each other, as seen in Fig. 217 (2).

These lines of force can be traced by a small compass the same as by using iron filings. Should a compass be moved through the magnetic field, the north pole of the needle will always point in the direction of the lines of force, and the center or pivot of the needle will describe a path, or circuit, coinciding with the lines of force.

Magnetic Induction.—Every substance as soon as it becomes magnetized, as well as every conductor of electricity, is surrounded by this magnetic field, and this action of developing magnetism in **other bodies** than itself is called **magnetic induction**.

In Fig. 218 (1) is shown the magnetic **whirl** which completely surrounds every conductor conveying a current of electricity.

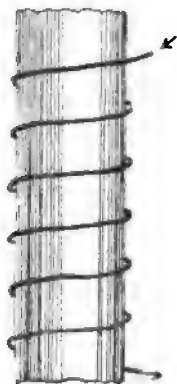
In Fig. 218 (2) is shown these lines of force forming a magnetic field around the end of a bar magnet.

Solenoid.—If a wire be made into a **coil**, and a current of electricity, be passed through this coil as shown in Fig. 218 (4), the coil partakes of all the properties of a permanent magnet. Such a coil is then called a **solenoid**. The magnetic field surrounding each turn of the wire, unites to form one **magnetic field**, which surrounds the entire coil similar to the field that surrounds a single bar magnet, as illustrated in Fig. 217.

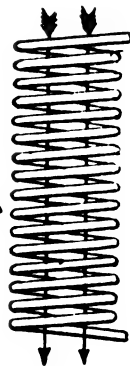
The solenoid will retain its magnetic properties only as long as the electric current passes through it. The direction of the lines of force as shown in the above illustration are the same as those of a permanent magnet, issuing from one end and entering into the other end of the coil. If the coil be suspended so as to be free to turn, it assumes a position such that its axis will



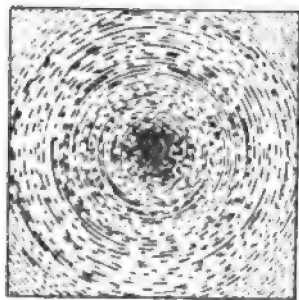
3



4



2



1. Magnetic Whirl. 2. Magnetic Field Around a Conductor.
3. An Electro-Magnet. 4. Solenoid Showing Direction
of Lines of Force.
Fig. 218.

point north and south, and so act like a compass needle.

The strength of the magnetic field of a solenoid **varies** with the **strength** of the current flowing through the coils, and the number of **turns of wire** composing the coils, it being in direct proportion to same.

A solenoid therefore differs from a permanent magnet in that its magnetic powers vary, and further in being under perfect control. Should the current be **stopped** altogether, the solenoid instantly **loses** all its magnetic properties.

Electro-Magnets.—As the field of a magnet is strongest **within** its windings, if we place a bar of soft iron within the coils as shown in Fig. 218 (3), this bar or core will become at once strongly magnetized, and can be made in this way a powerful magnet. A coil provided with such a core is called an **electro-magnet**. This core remains a magnet only while the current is flowing through the coil, and the instant the current is shut off, the core loses all its magnetic properties.

In order to force the current through each turn of the wire its entire length, and also permit it to be closely wound around the core, the wire is **insulated** throughout its entire length. By being insulated, or covered with some non-conducting material as silk, cotton or guttapercha, the current is prevented from being short **circuited** or from otherwise being wasted.

The presence of the iron core enormously increases the strength of the magnetic field, and this increase continues until the iron core becomes **saturated** with the magnetic lines of force, at which point any further increase in the current will produce only a slight increase in the strength of the field.

Magnetic Induction.—We have seen that all magnets are surrounded by a magnetic field, and also that

electric charges will induce a current of electricity in other bodies brought in contact with them.

When a substance is brought within a magnetic field, a current of electricity is produced in it the same as if it had been brought in contact with an electric charge. Electric currents produced in this way are called **induced currents**, and by this process of induction one body may become electrofied or magnetized by simply being brought in the presence of a magnet, or another electrofied body; the same as a substance becomes heated by being brought near a heated body, without ever coming in contact with it. The magnetic field which surrounds the magnet, or a wire carrying a current of electricity, can be compared to a highly heated stove which imparts its heat or energy to everything in the area heated by it.

Induced Currents.—The induced currents of electricity are usually produced by moving a body **across** a magnetic field, and thereby cutting the lines of force. This produces a current in the conductor or moving body, though it makes no difference whether the magnet itself or the conductor is moved, just so the lines of force which emanate from the body are cut.

This can be clearly seen if a magnet be quickly thrust into a coil of wire, as a momentary current will be produced around the wire, and this current will continue so long as the magnet is kept in motion.

The quicker the magnet is moved back and forth in the coil, the greater will be the strength of the current induced in the coil.

Withdrawing the magnet from the coil, produces a flow of current in an **opposite** direction to that produced by thrusting it in the coil.

If we join the two ends of a wire so as to make a

complete circuit, and move this wire rapidly in front of a magnet, a current will be induced in the wire.

This action of the magnet in producing an induced current in the wire, is **called electro-magnetic induction**.

Upon this property of electricity, which was discovered by Faraday in the year 1831, all dynamo-electric machinery is based, as well as all induction coils and alternate current transformers.

When a wire carrying a current of electricity is brought **near** another wire carrying no current, there is excited in the latter wire a sympathetic current, but which moves in an **opposite** direction to that of the current in the first wire. While this current, which is called as we have seen an induced current, is much weaker than the current in the first wire, in all other respects it is **exactly** similar, and produces the same **effects**.

Such induced currents are produced **only** by an **alternating** current, as will be hereafter shown. As its uses are universal, in fact, are the foundation upon which almost all applied electricity rests, its principles must be thoroughly understood.

Conductors and Non-Conductors.—Conductors are substances which readily allow an electric current to pass from one part of them to another.

Non-conductors, or insulators as they are most frequently called, are those substances which do not permit a free passage of electricity, as they offer a certain resistance to its passage.

For instance, one end of a glass rod can be electrofied, and yet the other end remain wholly **unaffected**, as glass is a **poor conductor**. On the contrary, when any metallic substance is charged with electricity, however small may be the charge, the electricity is at once uni-

formly distributed over its **entire** surface. This is because metals offer but little resistance to the passage of electricity, and hence are **good conductors**.

As all bodies offer a certain amount of resistance to the passage of an electric current, and none entirely resist it, there are no **perfect** conductors, and likewise no **perfect** non-conductors.

The following list of substances is arranged in order of increasing resistance, viz.:

Conductors.	Partial Conductors.	Non-Conductors or Insulators.
Silver.	Cotton.	Oils.
Copper.	Dry wood.	Porcelain.
Other metals.	Marble.	Wool
Charcoal.	Paper.	Silk.
Water.		Resin.
The body.		Guttapercha.
		Shellac.
		Ebonite.
		Paraffin.
		Glass.
		Air.

From this it can be seen that silver is the best conductor, and air the poorest. Air is therefore the best non-conductor or insulator.

Copper is chiefly used in all electrical work, as it is not only one of the best conductors, but also one of the most ductile and strongest, and at the same time the cheapest.

Transmission.—Electricity is transmitted over the **surface** of a body, and not **through** the interior, as is heat and light. The interior of a conducting body can be made hollow, or even filled with a non-conducting material, and it will have no effect upon its conductivity.

Electrical Measurements.—The four principal units used in the measurement of a current of electricity are:

The **Ampere**, or the unit denoting the rate of flow of the current, or its **strength**.

The **Volt**, or the unit of electrical potential, or **pressure**.

The **Ohm**, or the unit of resistance.

The **Watt**, or the unit of power, and is obtained by multiplying the current by the voltage, or by multiplying the square of the current by the resistance.

For large units the term **kilowatt** is used, which is equal to 1,000 watts, the abbreviation being K. W. The kilowatt hour is the energy expended in one hour when the power is one kilowatt.

Analogy.—The relation of the first three units can be better understood by the analogy often used of the flow of water through a pipe. The force which causes the water to flow through the pipe is called the head, or **pressure**; that which **resists** the flow is the friction of the water against the pipe, while the **rate of flow**, or current, may be expressed in gallons per minute. Now, as the pressure, or head increases the rate of flow, or current, increases in proportion, but as the resistance increases the current diminishes.

In the case of **electricity**, the electromotive force, or potential, corresponds to the head of water, or **pressure**; and the **resistance** of the conductor, to the friction of the water against the pipe; while the **strength** of the current is the ratio of the electromotive force to the resistance of the conductor. This ratio was discovered by Dr. Ohm, and is therefore called Ohm's law, and is the foundation of applied electricity, for there is hardly a problem in electrical work in which it does not enter.

Ohm's Law.—This law is usually expressed algebraically, thus:

$$\text{Strength of current} = \frac{\text{Electromotive force.}}{\text{Resistance.}}$$

$$\text{or Amperes} = \frac{\text{Volts}}{\text{Ohms.}}$$

$$\text{or } C = \frac{E}{R} \text{ as it is commonly expressed,}$$

in which C equals current, E equals the electromotive force expressed in volts, and R equals resistance, expressed in Ohms.

From this formula is derived $E = C \times R$, or $R = \frac{E}{C}$, these terms all being dependent upon each other. For watts we have the formula $W = E \times C$.

With any two of these terms given, it can be seen that the third term can readily be found. As seen, the current varies **directly** as the voltage varies, and **indirectly** as the resistance varies. That is, the current increases when the voltage increases, and decreases when the resistance increases. With the above four formulae any calculation in electricity becomes most simple. For instance, suppose you wish to find what current will flow through a resistance of 3 Ohms, at a pressure of 6 volts.

Substituting in formula (1), we have C (amperes) equals $\frac{6}{3} = 2$ amperes.

Again, we have a lamp the resistance of which we

know to be 12 Ohms, and we are using 2 amperes of current; what E. M. F. (volts) is necessary?

Using formula (2), we have E (volts) equal $2 \times 12 = 24$ volts.

Suppose we wish to know the resistance of a wire coil through which a current of 6 amperes will pass with 20 volts pressure?

Substituting in formula (3), we have R (Ohms) equal $\frac{20}{6} = 3 \frac{1}{3}$ Ohms. Lastly, we have a small motor

taking 2 amperes at 5 volt pressure to run it, how many watts of current does it consume?

Substituting in formula (4), we have W (watts) equals $2 \times 5 = 10$ watts.

Method of Measurements.—To ascertain the amount of current flowing in a circuit an ammeter, which is designated in Fig. 219 as A, is inserted in **series** in one of the mains. The whole of the current passing to the lamps L, therefore must pass through it and be measured.

A voltmeter, designated as V, is connected **across** the two main leads, or in **shunt** with the dynamo, and therefore measures the **difference** of potential between the two mains in volts.

Wattmeter.—This is an instrument for measuring the power consumed in a circuit supplied with a direct current, though wattmeters are now made for either direct or alternating currents.

As electrical **power** is equal to the product of the E. M. F. in volts and the current in amperes, these two factors must be taken into consideration in the construction of such an instrument.

This instrument is used to measure the electricity sold to customers, the record being kept in watt hours,

which is 1 volt x by 1 ampere x by 1 hour = 1 watt hour.

Construction of Meters.—Volt-meters are used to measure the potential **difference** between any **two** points in a circuit, and are therefore connected **across** the circuit.

An **ammeter** is used to measure the **volume** or **amount** of the current passing through a circuit, and is therefore connected in the circuit in series.

The principle of their construction is the same as that of the differential galvanometer, which is an instrument for **comparing** two currents. The galvanometer consists chiefly of two separate coils, or two similar independent windings.

If equal currents are passed through these coils, or windings, in opposite directions there will be no deflection of the needle, but if the currents are **unequal**, the deflection of the needle will be proportional to the **difference** between the two currents.

Voltmeter.—The Weston voltmeter, which is one of the most accurate voltmeters made, consists of a horizontal permanent magnet. Between the pole pieces of this magnet is fixed a cylindrical piece of soft iron, which serves merely to conduct the lines of force. A coil is placed between these poles and supported by jewel bearings inserted in fixed brass cups. A directive force is given to this coil by two delicate springs fastened at each end of the coil, and made to oppose each other. The coil carries a pointer which swings over a scale graduated in volts. The current is led to and from the coil through these springs, a high resistance being connected in series with the coils, which permits only a small part of the current to act upon the coil.

Ammeter.—There is no difference in the construc-

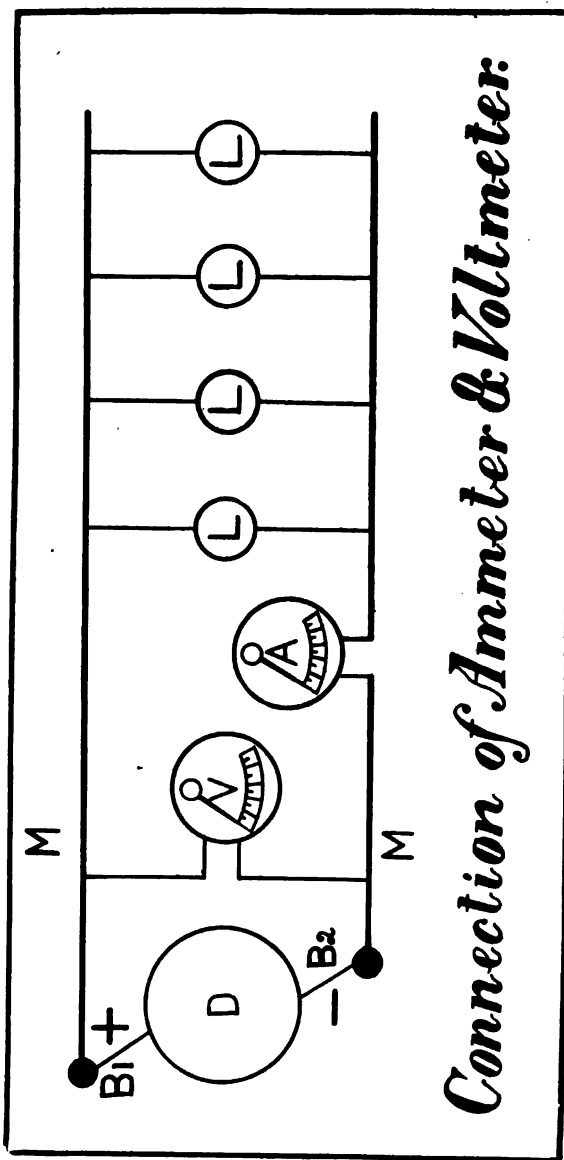


Fig. 219.

tion of an ammeter and a voltmeter, except in the **re-sistance** of the instrument. In the voltmeter, there should be a very high resistance so as to take only a very small current for its operation. In the ammeter, which is connected in series in the main circuit, the resistance should be as **low** as possible so that the energy consumed will be slight.

Wattmeter.—This instrument consists essentially of **two** coils of insulated wire, one fine and the other coarse, so connected in the electric circuit that they act upon each other.

CHAPTER XXV.

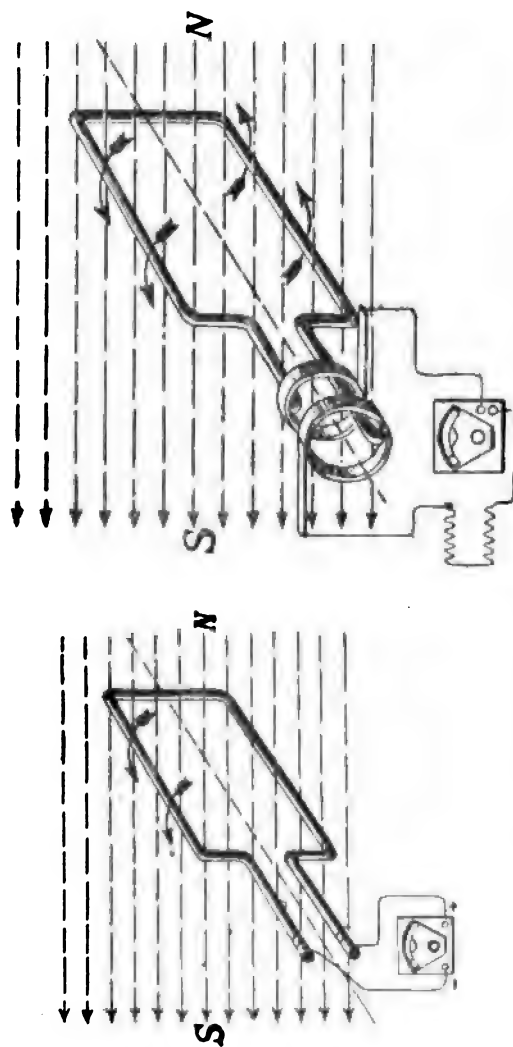
DYNAMOS AND MOTORS.

Theory of the Dynamo.—If a rectangular coil of copper wire is placed in the center of a magnetic field, with its plane lying perpendicular to the lines of force, as shown in Fig. 220 (1), the coil will in this position enclose the greatest possible number of lines of force. So long as the coil remains **at rest** in the magnetic field, no E. M. F. will be generated; but should the coil be **rotated** on its magnetic axis, as shown by the broken line, and in the direction indicated by the arrows, then the coil cuts the lines of force at right angles, and a current is at once generated. The E. M. F. generated in the upper side will cause the current to flow from left to right, and in the lower side of the coil from right to left, thus making a complete circuit of the coil.

Should a voltmeter be connected to the two ends of the coil, as shown in this diagram, the E. M. F. generated in the coil will be indicated by the deflection of the index needle.

As the current flows towards the lower terminal of the coil where it is connected to the voltmeter, and from thence out on the external circuit, this terminal becomes the **positive** pole or terminal, while the upper end of the coil becomes the **negative** pole or terminal, as through this coil the current **returns** to the coil after completing the entire circuit.

If the speed of rotation is kept constant throughout each revolution, the voltmeter will show the E. M. F. becomes **greater** as the coil revolves from its vertical position, and it continues to increase until the coil reaches the plane **parallel** to the lines of force, which will be when it reaches one quarter of its revolution, at



1. Coil Cutting Lines of Force. 2. Coil with Collecting Rings and Brushes Attached.
Fig. 220.

which point the coil cuts the lines of force at **right angles**, and the E. M. F. will therefore be at its **maximum**.

From this point the E. M. F. declines until the coil reaches one-half of its revolutions, when it again is in a vertical position, and again the E. M. F. will be at its minimum.

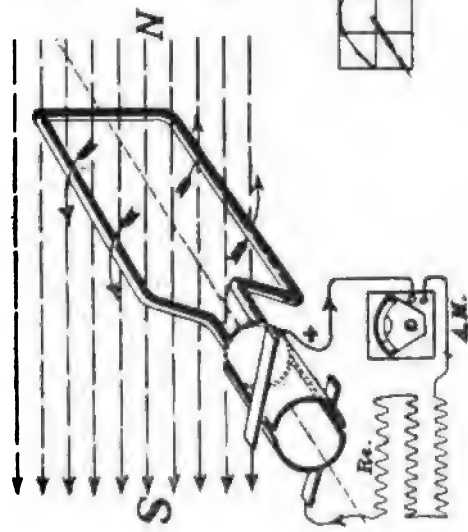
During the next quarter of its revolution, that is from the position of one-half of a revolution to that of three-quarters, the E. M. F. again **rises** until it again reaches its maximum when the coil is at a point three-quarters in its revolution, when it again **declines** until it is at zero at end of the revolution.

Thus, the increase and decrease of the E. M. F. will continue throughout **each** revolution of the coil.

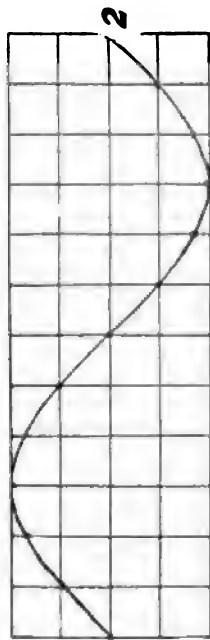
Electric Generator.—This apparatus, which is the simplest form of an electric generator, demonstrates the principles first enunciated by Faraday, as follows:

“When a conductor is moved in a field of magnetic force in any way so as to **cut** the lines of force, there is an electromotive force produced in the conductor, in a direction at right angles to the direction of the motion, and at right angles also to the direction of the lines of force, and to the right of the lines of force, as viewed from the point from which the motion originates.”

The rise and fall of the E. M. F. during one complete revolution of the coil, can be graphically shown by means of cross-section paper, as illustrated in Fig. 221 (2). The **horizontal** divisions represent equal intervals of time, and the sum of these divisions is the total time required by the coil in making one complete revolution. The **vertical** divisions represent the E. M. F., and the **sum** of these divisions is the total E. M. F. that is being generated in the coil in passing through each complete revolution.



1. Coil with Commutator. 2. Current During One Revolution of the Coll. 3. Current Rectified by Commutator. Fig. 221.



In Fig. 220 (2) is shown this coil with its two ends connected to collecting rings upon which two brushes, made of two copper strips, are made to bear, and to which brushes the external circuit is connected. In this way the E. M. F. that is generated in the coil **flows out** and over the entire external circuit through the **positive** brush, returning through the upper or **minus** brush to the coil.

In Fig. 222 is shown **two** such coils being used, each coil sending out its current the same as done by one coil.

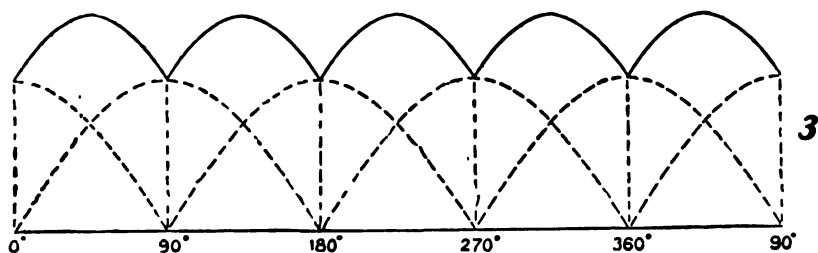
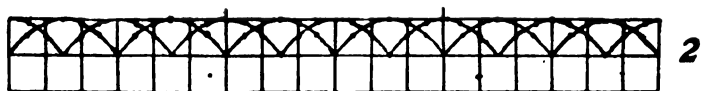
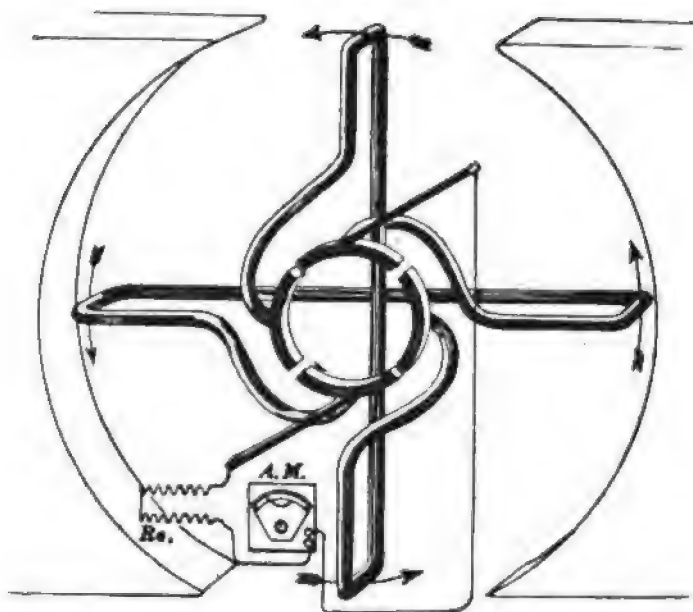
As seen from this diagram, the current **alternates** from one direction to the opposite direction during each revolution of the coil, being first above the axis, or middle line as shown in the diagram, and then below this line, which shows that **all** currents when generated, are **alternating** currents.

In Fig. 224 is shown the ordinary type of a generator, on which can be seen the location of the commutator.

Commutator.—Should these collecting rings be made in **two halves** or **segments**, instead of a solid ring, and **each** segment connected to one end of the coil and these segments **insulated** from each other, then it is no longer called a collecting ring, but a **commutator**.

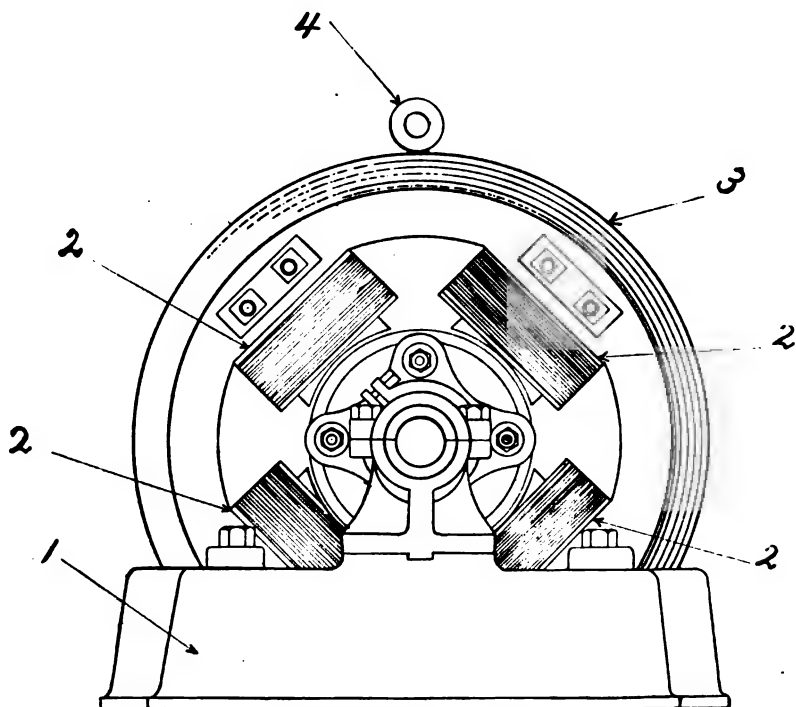
The purpose of a commutator is to **change** the flow of the current, so that it will always flow in the **same** direction through the external circuit, that is, it **rectifies** the current so as to make it a **direct** current instead of an **alternating** current.

Operation.—When the coil is in a vertical position both brushes rest against both segments, but as soon as the coil starts on the first half of its revolution, the minus brush rubs against only **one** segment, and the



1. Two Coils Showing Commutator. 2. Diagram of Direct Current from Two Coils.

Fig. 222.



Generator Showing Fields.

1. Base. 2. Fields. 3. Casing. 4. For Handling.

Fig. 223.

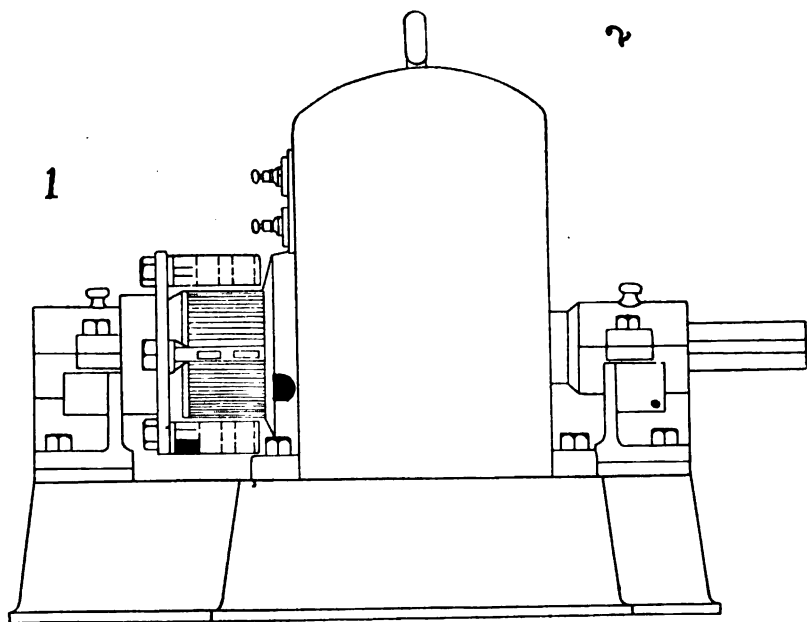
plus brush through which the current goes out on the circuit, rests against the other segment.

We have seen how the current in the coil flows in **two** directions during each revolution. As the coil rotates, the E. M. F. gradually decreases until when it reaches 90 degrees, or the end of the first one-fourth of its revolution, the E. M. F. is **zero**. At this point the segments are located so that the brushes are about to break contact with one segment and make contact with the other. Further rotation induces an E. M. F. in the **opposite** direction, but the segments have then passed from one brush to the other, and the direction of current in the external circuit therefore remains unchanged.

In Fig. 221 (3), is shown a diagram of a **direct current**, that is, the current as it flows over the external circuit when it is rectified by the use of a commutator. It will be seen from this diagram that the curve is entirely above the middle line of the diagram, and therefore the current flows always in the **same** direction.

GENERAL CONSTRUCTION OF A WESTERN ELECTRIC COMPOUND GENERATOR.

Frame.—The cross-section of generator frames must be sufficient not only from the **magnetic flux** that it is intended to care for, but must also be of such form and section as to insure perfect **mechanical stability**. In larger generators mechanical considerations demand a form and size of section other than would be necessary by the requirements of the magnetic flux. It is for this reason that larger generator frames are of cast iron, while in the smaller ones, where the section necessitated by the requirements of the magnetic flux is greater than would be necessitated by mechanical strength, a special material of high magnetic perme-



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Generator Showing Commutator.

1. Commutator. 2. Casing. 3. Shaft and Bearings. 4. Base.

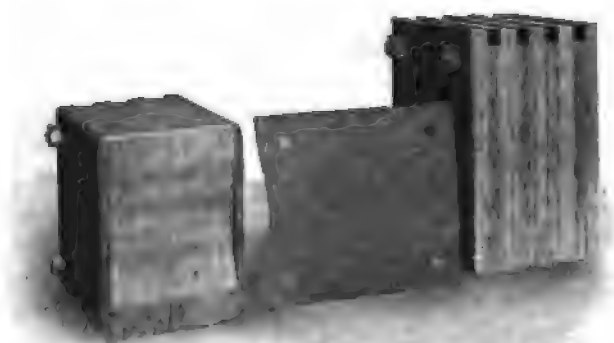
Fig. 224.

ability is used. By reason of this construction the best results are obtained with a minimum weight of material.

In their standard construction the frame is divided **vertically**, which permits drawing the yoke apart horizontally, allowing the armature to be inspected or removed. It is also a great advantage in isolated plants of limited distance between floor and ceiling as the frame can be easily handled without access to cranes or other lifting devices. In Fig. 235 is shown a generator with the frame withdrawn, showing fields and armature.

The method of bolting the frame to the extended engine sub-base allows adjustment both horizontally and vertically, insuring a **uniform air gap** and a **perfectly balanced magnetic field**, conditions necessary to obtain the best operation of a generator. On account of limited width of engine room it is sometimes impossible to make use of the vertically divided frame construction; a **horizontally** divided yoke is then used.

Pole Pieces.—In generators having **solid** pole pieces there is a considerable loss due to the **eddy currents** in the pole tips. This results in materially **reducing** the efficiency of the outfit with the consequent **increase** in the temperature of the pole tips. To eliminate as much as possible these wasteful currents, the laminated pole piece construction is adopted, the pole pieces being built up of thin sheets of thoroughly annealed mild steel, the various sheets being both bolted and riveted together. Fig. 226 shows one of the separate pole-piece sheets and also a pole piece assembled ready to be placed in the clamping plate which is used in the process of molding. The metal of the frame is poured around the outer and jagged ends of the pole pieces. By this construction an area of magnetic contact between the pole pieces and the frame is obtained which is **nearly three times greater**



Pole Pieces.



Field Coils.
Fig. 226.

than the maximum possible area of the **bolted pole-piece** construction. In addition to this a partial weld is obtained between the pole pieces and the yoke. By these means a frame is obtained, the **magnetic resistance** of which is reduced to the lowest possible point and the liability to an unequal magnetic distribution, with the attending sparking, is much less than would be obtained by other forms of construction.

While the usual methods employed in building generators having the pole pieces cast **integrally** with the frame, permit, in the finished product of **variations** in mechanical placement of the pole pieces, the method illustrated for assembling and holding the pole pieces in place during the process of molding, has been found to entirely eliminate this difficulty, and, as stated above, to assure at the same time a better mechanical and magnetic joint than would be possible in a generator having the pole pieces **bolted** to the frame. In order to assure the **similarity** of the pole tips of all pole pieces, a condition necessary for uniform magnetic distribution and sparkless operation, each tip is machined to a standard gauge after the pole pieces are cast into the frame.

Field Coils.—In the standard construction of these coils, as shown in Fig. 226, the shunt and series field coils, although separately wound and insulated, are mounted on a single metallic spool. This method has the advantage of the additional mechanical protection, which facilitates not only the shipment but also the handling of the coils during erection

Armature Cores.—The armature is of the iron-clad type, as shown in Fig. 228. In order that it may have a minimum loss the armature core is made of thin discs of doubly annealed sheet steel. After the slots have been carefully punched in the periphery of these discs,



Pole Pieces in Frame.
Fig. 227.

the final annealing is given. By this method any hardening effect caused by the punching of the slots, is removed. Radial ventilating spaces are provided, which connect with horizontal openings in the armature center, allowing a thorough system of ventilation. The smaller armatures are built up of **continuous rings**, while in the larger ones, on account of the difficulty of obtaining iron in sheets sufficiently large, the method of building in **segments** has been adopted.

Winding Armature.—In winding the armature, as shown in Fig. 229, **solid bars** of specially drawn copper are used. The coils are enlarged in cross-section at the ends of the armature, Fig. 230, thus obtaining a very low armature resistance and a consequent gain in efficiency, while all the advantages of a solid bar winding are secured. This results in higher efficiency and lower temperature.

The bars are formed into coils before being placed on the armature so that when complete a perfectly symmetrical and balanced winding is secured, as shown in Fig. 231. They are insulated individually and in groups, the insulation, as well as the bar itself, being continuous from segment to segment of the commutator. At the various steps in the insulation process the bars are immersed in insulating compound and thoroughly baked. An illustration of the armature core prior to placing the coils thereon is shown in Fig. 228. The shape of the slot and the notches near the top of the slot permit of retaining the coils in place by means of fibre wedges. In addition to these wedges, on the smaller sizes the coils are held in place at the pulley or engine end of the armature by a brass ring extending over and clamping the ends of the coils, giving the armature the appearance as shown in Fig. 232. In the



Armature Core and Commutator Ready for Winding.
Fig. 228.

larger sizes this construction is not used but a finishing plate is placed at the pulley or engine end of the armature and band wires are used on that portion of the armature winding lying outside of the armature core.

The armature, after being built up in this way and after having the commutator and armature winding placed in position, may then be mounted on the engine shaft.

Commutators.—the commutators are of a very rigid construction, enabling them to withstand strains due to expansion and contraction and centrifugal force. The segments are made of the very best drawn copper, and have riveted to them rolled copper tangs. These segments are **insulated** from each other by specially prepared mica of a sufficient degree of hardness to produce a uniform wearing surface. In all but the smaller sizes the segments are mounted upon a cast-iron center from which they are insulated by mica. The completed commutator is then mounted upon the extended hub of the armature center, thereby permitting it to be removed from the armature without disturbing the armature mounting. A thorough system of **ventilation** is provided by means of horizontal air ducts. In the smaller sizes, in order that this ventilation may be obtained, it is necessary to cast the commutator center integrally with the armature center. The segments are then mounted in the manner described above. This construction does not permit of the removal of the commutators from the armature center, but as the total weight of the completed armatures in the sizes in which this construction is used is small, in case of accident the complete armature may be handled without any difficulty.

Brush Holders.—Fig 233 illustrates the brush holder mounting and shifting device. Each set of brush holders



Armature During Winding.
Fig. 229.

is mounted upon a brush holder arm supported from a circular ring. This ring is carried in supports projecting from the yoke, the entire device being moved around the commutator by means of a hand wheel at the side of the machine. It will be readily seen that this arrangement gives an extremely stable construction.

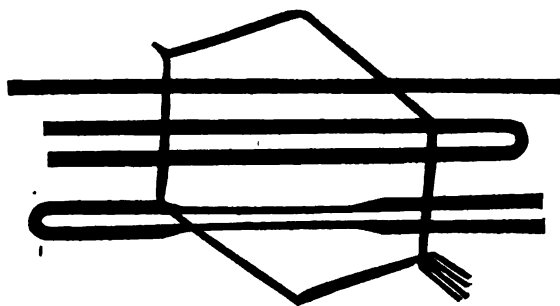
The brush holders are designed so that the brushes may be moved in a direction radial to the surface of the commutator. Each brush is held firmly in a clamp in such a manner that the current does not pass through any sliding contacts.

The current is conducted from the clamp through copper strips, thus eliminating any danger of affecting the tension springs. The brush holder clamp and brushes themselves are small and light, and, having very little inertia, follow the commutator quickly.

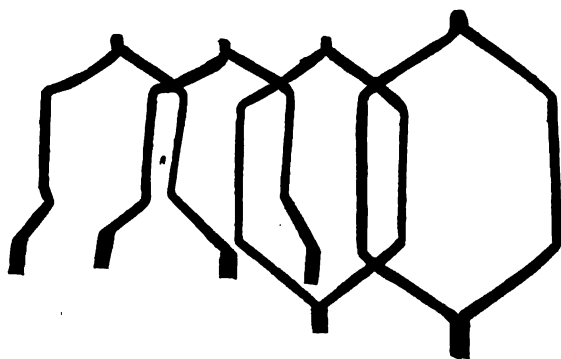
Any brush may be lifted from the commutator without disturbing the adjustment of the others, and all brushes may be adjusted independently. A single arm with brushes and with parts is shown. By means of the eccentric insulating bushing, as shown in Fig 234, each individual arm may be adjusted to obtain perfect uniformity of spacing of the brushes about the commutator.

Inspection and Tests.—During the process of manufacture, all parts are subjected to rigid inspection and tests and the completed machines are run for a sufficient length of time to make sure that they come within the guaranteed limits of heating, sparking, etc. The insulation of the various parts of the machine and the completed machine are tested by the application of a high voltage, in accordance with the standard specifications adopted by the American Institute of Electrical Engineers.

The Dynamo.—The dynamo is therefore a machine



Coils Enlarged for Armature Winding.
Fig. 230.



Symmetrical and Balanced Coils for Armature Winding.
Fig. 231.

driven by power, usually steam or water, and producing the necessary **pressure** for the production of an electric current.

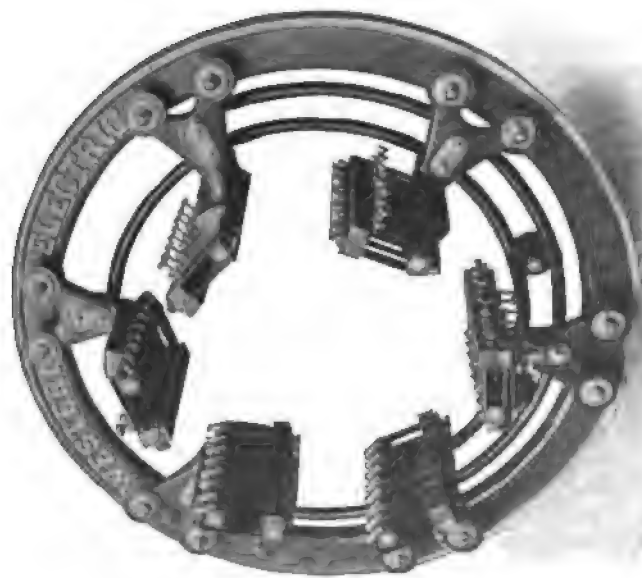
A dynamo when in action is like a cistern at a high level, or a pump, for it urges or forces the current through the conductor. Without such **force** or **pressure** as produced by the dynamo, there would be no more flow of an electrical current, than there would be of water from one receptacle to another, when both are on the same level.

Classes.—Dynamos are classified into (1) Uni-polar, (2) Bi-polar, (3) Multi-polar machines, according to the number of pole pieces upon them. They are used for three principal purposes:

1. Incandescent lighting.
2. Arc lighting.
3. For distribution of power.

When used for **power** purposes, the machine is called a **generator**, that is, when it generates electricity to be used through motors. Such an electrical machine in its simplest form consists of two main parts: (1) an **armature**, which in revolving induces electromotive forces in the conductor wound upon it; (2) a field magnet, whose function is to provide a field of magnetic lines to be cut by the armature conductors or coils as they revolve. In all dynamos, whether for direct or alternating currents, these two parts are the same. Usually the field magnet remains stationary while the armature rotates, but in recent patterns of alternators, the armature remains stationary, and the field magnets rotate.

It is always the **field magnet** which maintains its magnetism steady during the revolution, while the magnetism of the **armature** alone regularly changes, and this



Brush Rocker Ring.
Fig. 233.



Completed Armature.
Fig. 232.

variation of the magnetism determines the type of machine. It has been found most convenient to supply incandescent lighting systems by the constant **potential** system, and arc lighting systems by the constant **current** system, as will be hereafter explained.

In Fig. 223 is shown the **fields** on the ordinary type of generators.

The essential difference as we have seen between a direct current machine and an alternator, as an alternating current machine is called, is the use of a **commutator** upon the former machine for rectifying the current, that is, to change it from an alternating to a direct current. The commutator is attached to the **armature** and revolves with it.

In the case of an alternator there is no need of a commutator, but metallic rings, known as collecting rings, take its place, the collecting brushes pressing against them, as shown in the illustrations.

The dynamo, therefore, consists of **five** essential parts, viz.:

- (1) The armature, or revolving part.
- (2) The field magnets which produce the magnetic field in which the armature rotates.
- (3) The pole pieces.
- (4) The commutator or collector.
- (5) The collecting brushes.

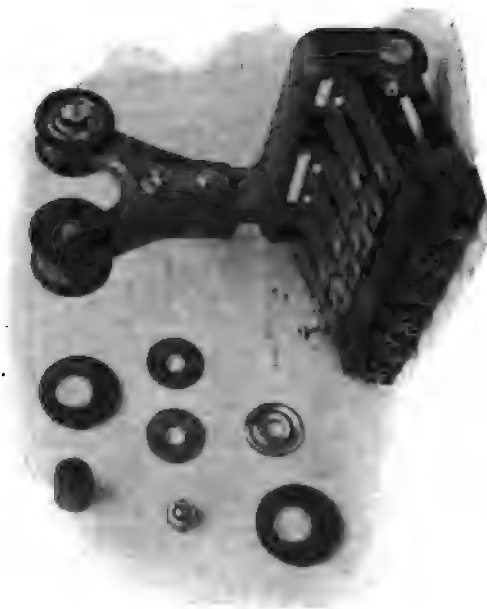
In Figs. 223 and 224 are shown the principal parts of a generator, or dynamo.

Types of Dynamos.—There are two principal types of dynamos: (1) Direct current, and the (2) Alternating current machine.

The direct current machines are divided into three classes: (1) Series wound; (2) Shunt wound; (3) Com-



Rheostat.



Brush Holder Arm with Eccentric Bushing Parts.

Fig. 234.

pound wound, depending upon the manner the field magnets are connected to the armature.

Series Dynamos.—The manner in which the connections are made on this type of machine can be seen from Fig. 238. In this type, the **whole** of the current generated in the armature, passes direct through the coils of the field magnet, which is wound with several turns of heavy wire, and thence out to the external circuit. The current in passing through the coils of the field magnet energizes same, creating a magnetic field between the N. & S. poles, in which magnetic field the armature revolves as shown clearly in the cut.

Shunt Wound Dynamos.—This type which is shown in Fig. 238, differs from the series wound machine in that the **whole** of the current does **not** pass through the field coils, but an independent circuit is used for exciting its field magnet. This independent circuit is composed of a large number of turns of fine wire, which are wound around the field magnet and connected direct to the brushes, so as to form a by-pass or shunt to the brushes and external circuit, in addition to the main current, which is taken off direct from the brushes. There are two paths presented to the current as it leaves the armature, viz.: The external circuit and the path through the field coils. Most of the current flows through the external path, as it offers much less resistance than the shunt path through the field coils, it being of much larger wire. The resistance of the shunt circuit is always made very great, as compared to the resistance of the armature and external circuit, as this circuit is used alone to secure a **closer regulation** of the machine than afforded by the series type. The strength of the current through the field coils rarely exceed 15 amperes, even in the largest size machines.



A Compound Dynamo with Frame Withdrawn, Showing Fields and Armature.

Fig. 235.

Compound Wound Dynamos.—This type, as shown in Fig. 238, is a combination of the series and shunt wound machines, the field magnet being wound with two sets of coils, one set being connected in series, and the other set in parallel with the armature and external circuit.

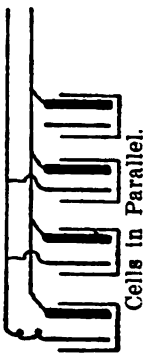
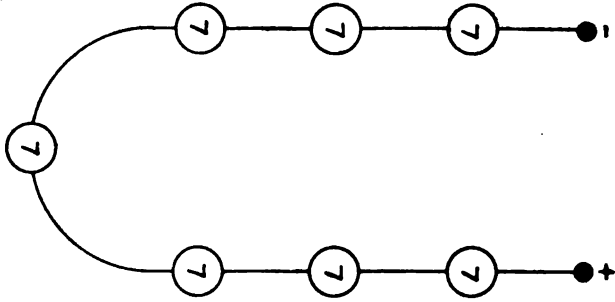
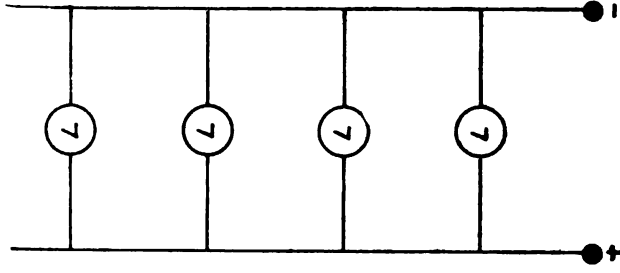
This affords a much closer regulation than the shunt type, and automatically maintains a constant pressure, and is therefore used almost exclusively for incandescent lighting.

Self-Exciting Machines.—The above three types are what is known as **self-exciting machines**, as they require no independent battery or dynamo for exciting their field magnets, but excite their fields themselves, as above described.

Separately Excited Machine.—In order to operate this type of machine, known as an **alternator**, an independent direct current dynamo or battery is necessary for exciting its field magnets, called an **exciter**, which is shown in Fig. 239. It is therefore not in general use for small installations, being principally used where an **alternating current** is required, as with an alternating current a self-exciting machine is impossible, owing to the fact that the fields cannot be magnetized with such a current, a direct current being necessary for this purpose, as above explained.

The E. M. F. and current of this type of dynamo is regulated by varying the strength of the magnetizing current produced by the independent dynamo or battery which is connected direct to the field coils. The strength of this independent current is regulated by the regulator R.

Coupling of Dynamos.—In large installations, such as central generating stations, it is neither economical



Cells in Parallel.



Cells in Series

Connection of Cells and Lights in Series and Parallel.

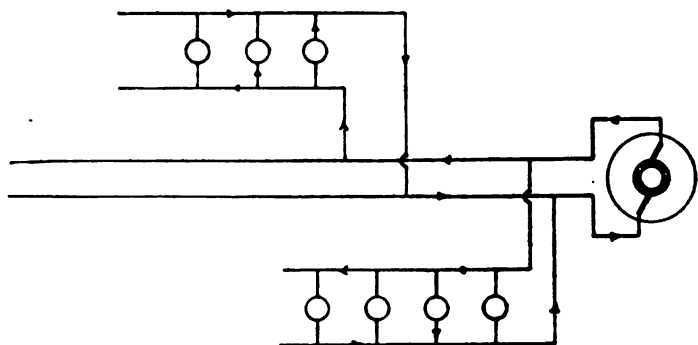
nor desirable that the **entire** current should be furnished from a single dynamo or generator. As it is economy to always work a dynamo at **full load**, or as near a full load as possible, it is manifest that this would be impossible with only one machine, owing to the fluctuation of the load. In order to secure a maximum efficiency it is usual to divide up the plant into a number of **units**, so that the load can be taken care of at all times, irrespective of its fluctuations. At the "peak" of the load, that is where the load is the heaviest, all the units can be worked, and as the load decreases the units can be cut out, so as to always keep a **full load** on the machines kept running.

The **output** of a dynamo is composed of two factors, the pressure, or voltage, and the current, or **amperage**. Either or both of these can be increased by the addition of **more machines**, the same as the boiler horse power of a plant can be increased by the installing of more boilers. The uses of electricity at the present time require the maintenance of either a constant current, or a constant pressure in a circuit, and to comply with these requirements it becomes necessary to connect the dynamos or generators together in several different ways.

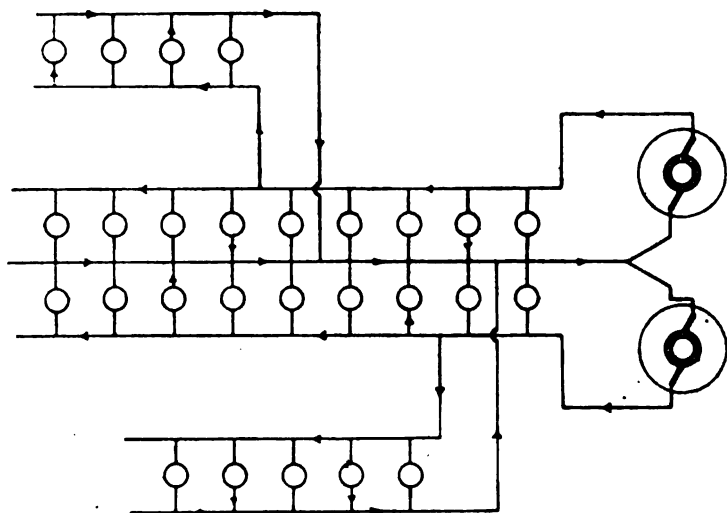
In coupling two or more **machines** in **parallel** the pressure or **voltage** of all the machines is kept constant, and the current or **amperage** alone varies.

In the **series** connection, the pressure or **voltage** of the machines is **increased**, while the current, or **amperage**, remains the same..

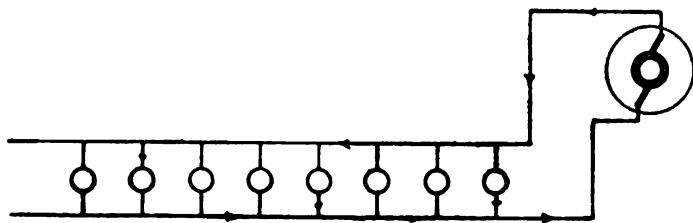
Fig. 236 shows the cells when connected in series and also when connected in parallel. Also, connection of **lights** in series and parallel.



Alternating System.



Three Wire System.
Systems of Connecting Lights.
Fig. 237.



Two Wire System.

Fig. 237 shows the principal systems of connecting incandescent lights.

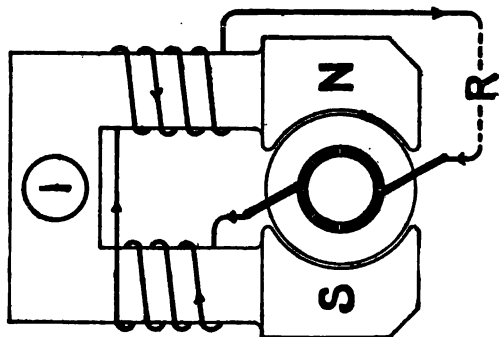
When the machines are connected in **parallel** all the positive terminals are connected together, and all the negative terminals the same way; or the positive and negative terminals of each machine can be connected respectively to two insulated copper bars, called omnibus or "bus" bars. When in **series**, the negative and positive terminals are connected to each other.

Shunt Dynamos in Series.—The following are the usual methods of connecting up dynamos so as to run either in parallel or series. To connect in **series** the positive terminal of one machine is connected to the negative terminal of the other. The ammeter, fuses and switch are connected through the outer terminals, as shown in Fig. 240.

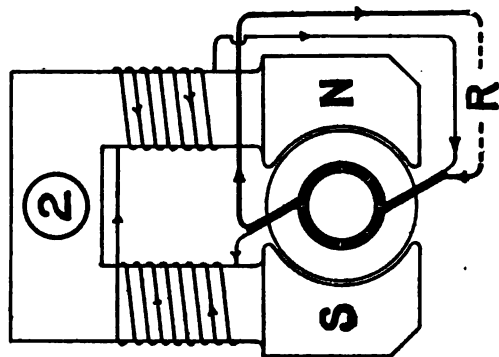
Shunt Machines in Parallel.—To connect shunt machines in **parallel**, it is only necessary to connect the positive and negative terminals of each machine respectively to the positive and negative "bus" bars, as shown in Fig. 243.

Series Dynamos in Series.—Series wound machines will run satisfactorily when connected in series, as shown in Fig. 242.

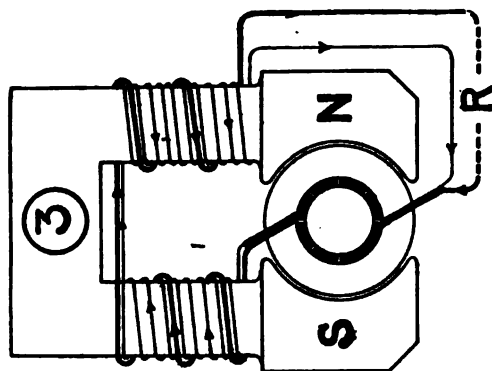
Series Dynamos in Parallel.—Series wound machines are not adapted to run in parallel, as machines of this type are not constructed for the purpose of maintaining a **constant pressure**. In order to operate such machines in parallel, an "equalizer" is necessary, as shown in Fig. 241. This is a third connection between the ends of all the **series** coils, where they join the armature circuit. This causes the whole of the current generated by all the machines to be divided among the series coils of the several machines. This maintains constant the



Series Wound.



Shunt Wound.



Compound Wound.

Classes of Electric Generators.
Fig. 238.

fields of the several machines, and maintains an equality of pressure, thereby preventing reversal of polarity, and keeping the machines together under all conditions of load.

Compound Dynamos in Series.—It is only necessary to connect the series coil of each together, as shown in Fig. 242. The shunt windings must be connected as a single shunt.

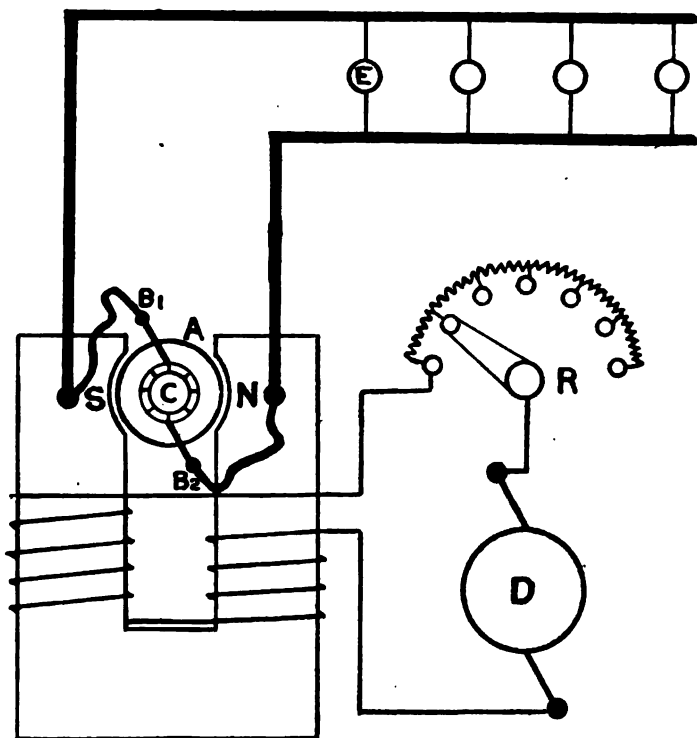
Compound Dynamos in Parallel.—Such machines will not run together satisfactorily unless the series coils are connected together by an equalizing connection, as shown in Fig. 244. The connection is the same as when series dynamos are connected in parallel.

Coupling of Alternators.—In order that the output of one alternator may be added to another it is necessary that the E. M. F. of each machine shall be in exact agreement, so that they will have equal frequencies, or be in **phase**, or in **step** with each other.

Method of Measurements.—To ascertain the amount of current flowing in a circuit an ammeter, which is designated in Fig. 219 as A, is inserted in **series** in one of the mains. The whole of the current passing to the lamps L, therefore must pass through it and be measured.

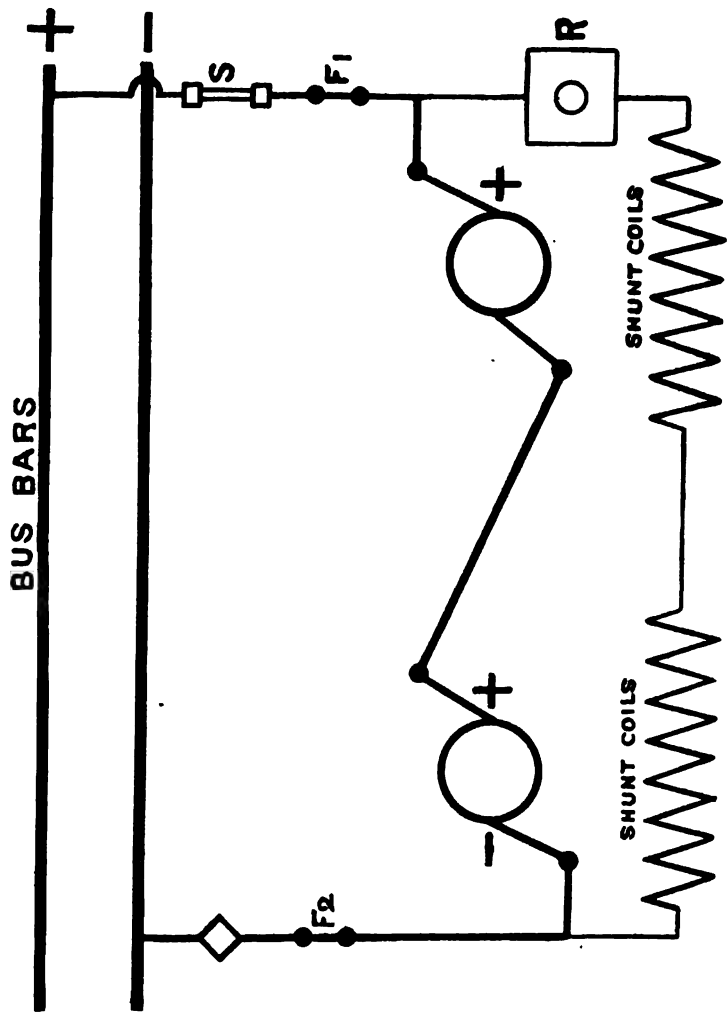
A voltmeter, designated as V, Fig. 219, is connected **across** the two main leads, or in **shunt** with the dynamo, and therefore measures the difference of potential between the two mains in volts.

Use of Different Types.—The series wound machines are used almost exclusively for street car motors, such a type being totally unfit for constant potential work. The shunt and compound wound machines are practically used for all power and incandescent lighting circuits. The constant current type is devoted



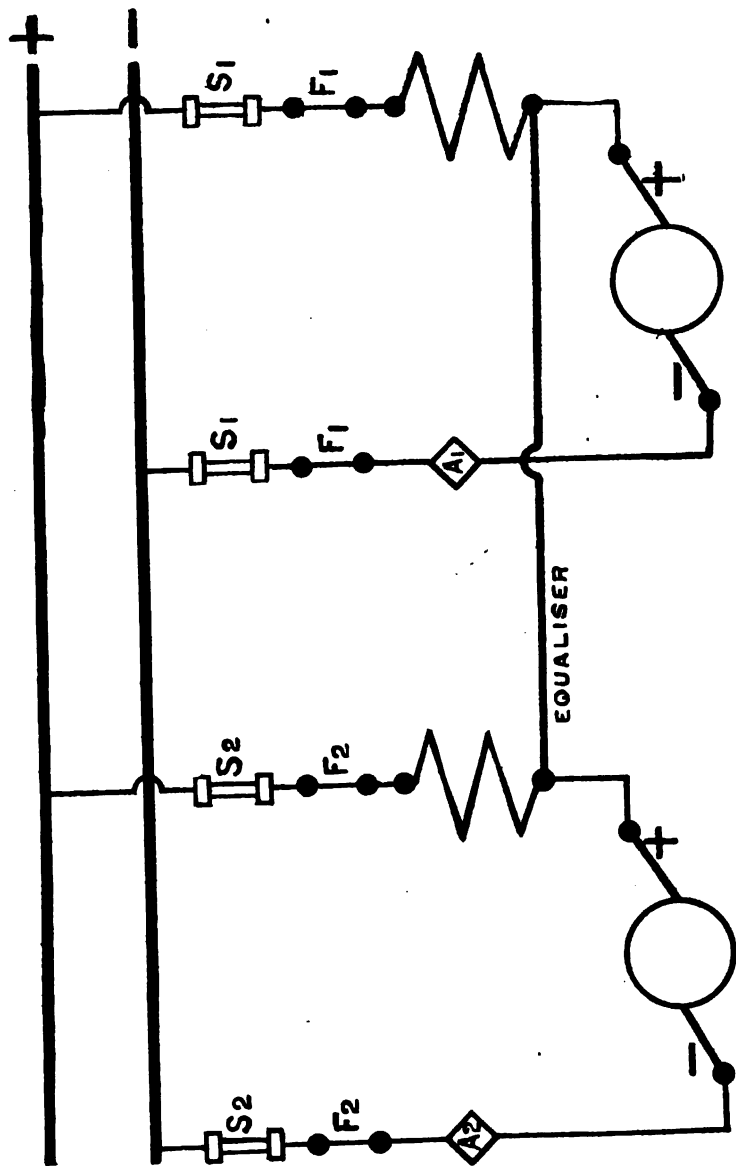
WINDING FOR SEPARATELY EXCITED DYNAMO.

Fig. 239.

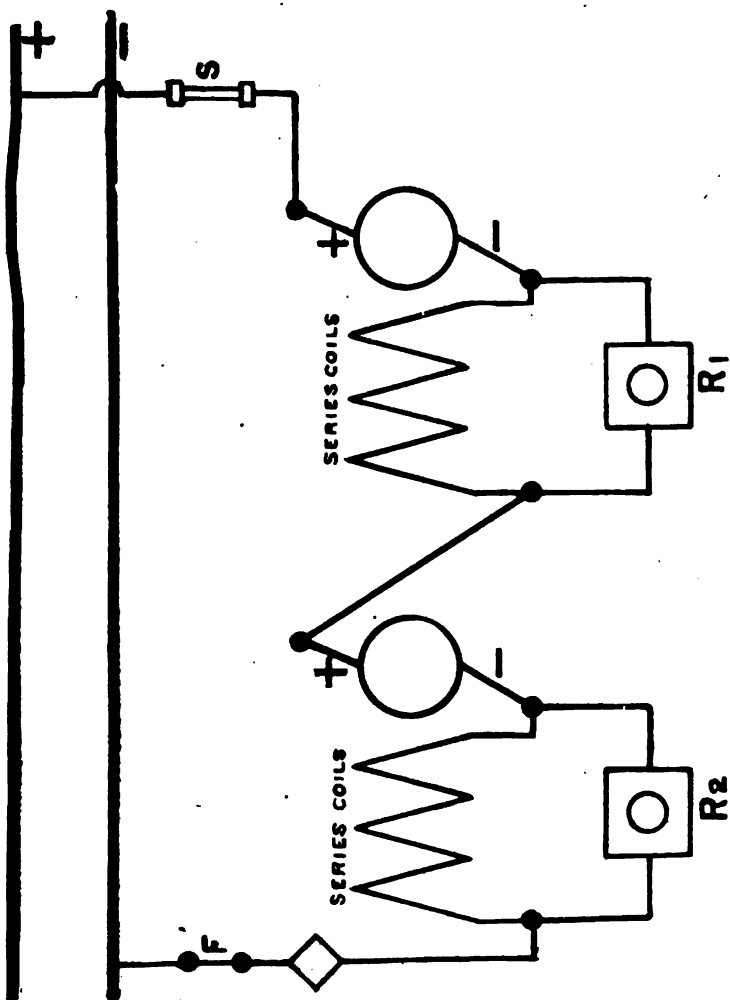


SHUNT DYNAMOS IN SERIES

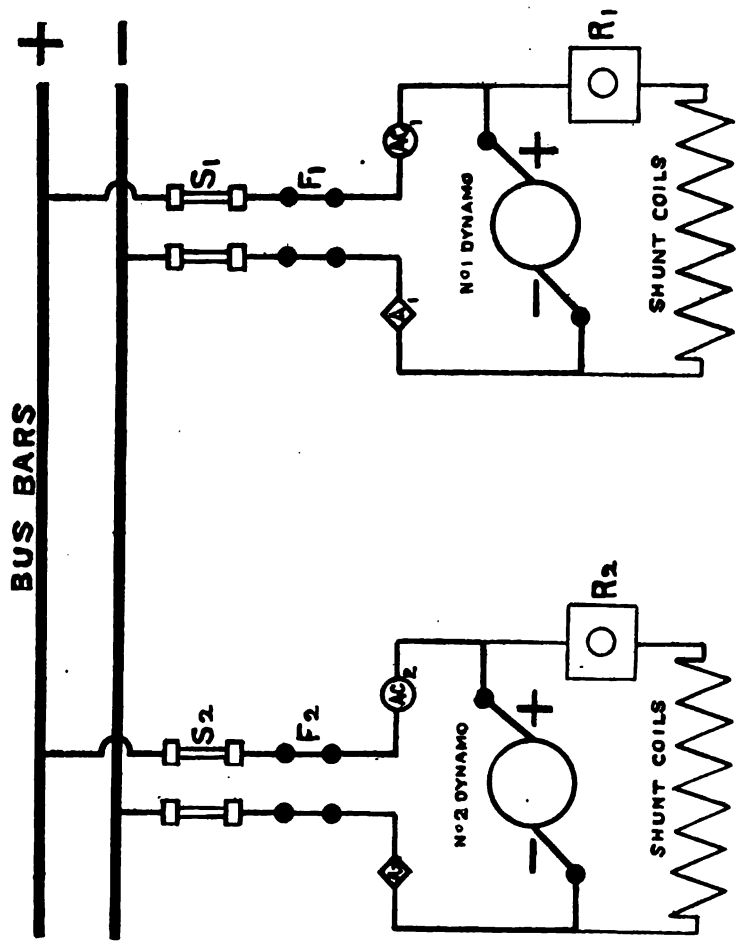
Fig. 240.



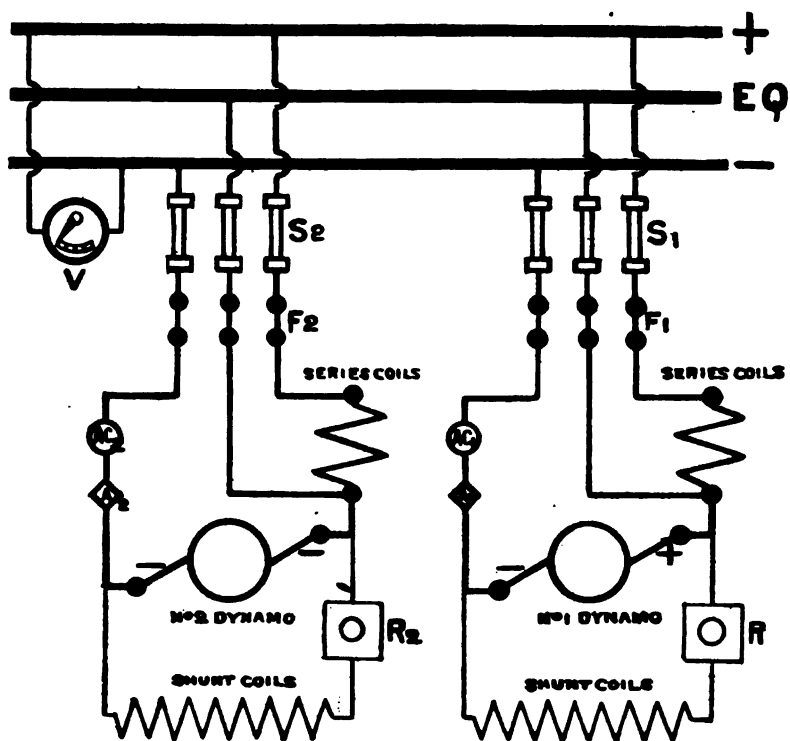
SERIES DYNAMOS IN PARALLEL
Fig. 241.



SERIES DYNAMOS IN SERIES
Fig. 242.



SHUNT DYNAMOS IN PARALLEL



COMPOUND DYNAMOS IN PARALLEL

Fig. 244.

mostly to arc lighting. Of the three types described above, the compound wound machine is by far the most used, owing to its close and automatic regulation.

Over-Compounding.—This is such a compounding of an electrical machine as produces under an increase of load an **increase** of voltage at its terminals. This is produced by placing a sufficient number of turns on the **series** coils so as to increase the difference of potential between the terminals of the machine above normal when the load increases. In this way the series coils are made to compensate for the drop in the armature and the external circuit.

Wagner Electric Generator.—In Fig. 246 is shown a view of this generator.

Western Electric Generators.—In Fig. 245 is shown a 125 K. W. generator, 125 volts and 125 R. P. M.

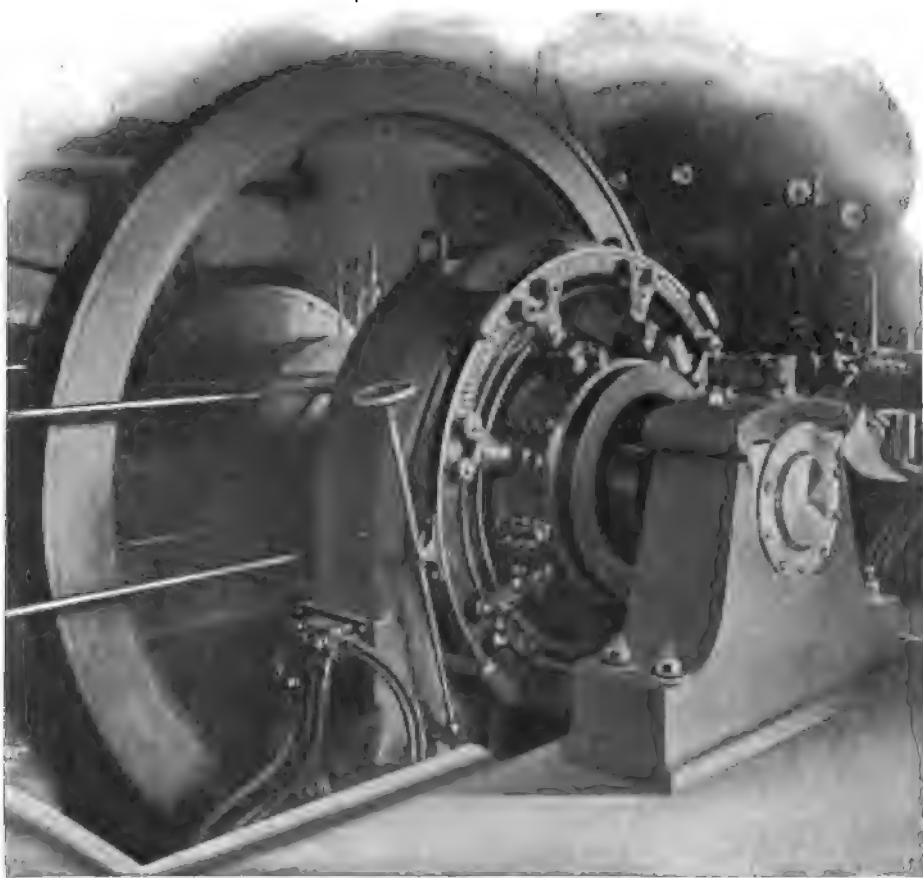
In Fig. 247 is shown a Western Electric 300 K. W. generator, 250 volts, 120 R. P. M.

In Fig. 248 is shown a 800 K. W. Western Electric generator, 80 R. P. M.

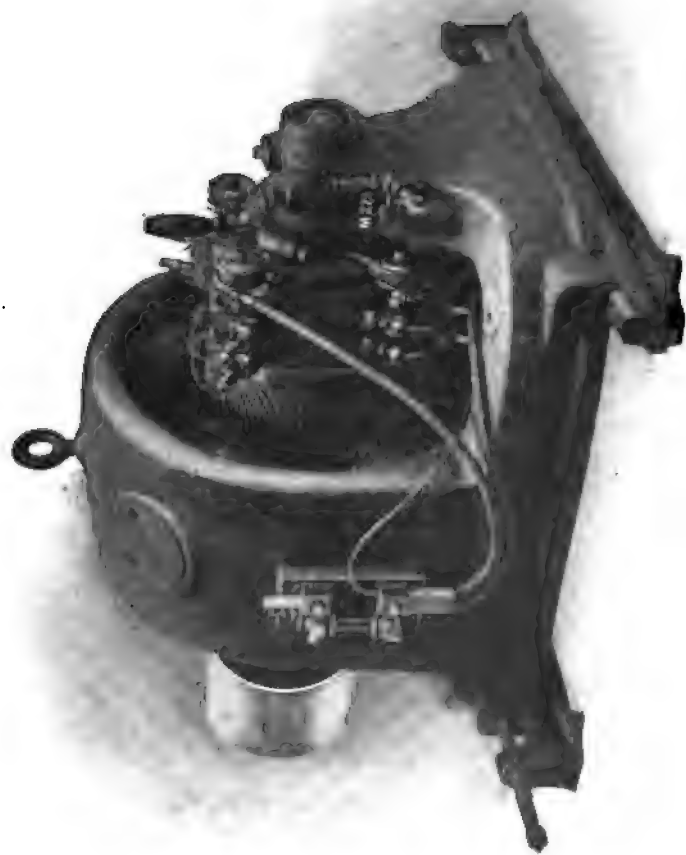
In Fig. 249 is shown a 40 K. W. Western Electric, 125 volt generator, direct connected to a **gas engine**, run at a speed of 290 R. P. M.

The Aldrich Electric Boiler Feed Pump.—In Fig. 250 is shown an electrical driven boiler feed pump.

The Marine Electric Elevator Machine.—In Fig. 259 is shown an elevator machine driven by an electric motor.



**A Western Electric 125 K. W. Generator, 125 Volts, 125 R. P. M.
Fig. 245.**



A Wagner Electric Generator.
Fig. 246.

CHAPTER XXVI.

OPERATION OF DYNAMOS AND MOTORS.

Installation.—As there is practically no difference in the construction of dynamos and motors, the directions for their installation and operation applies equally to both.

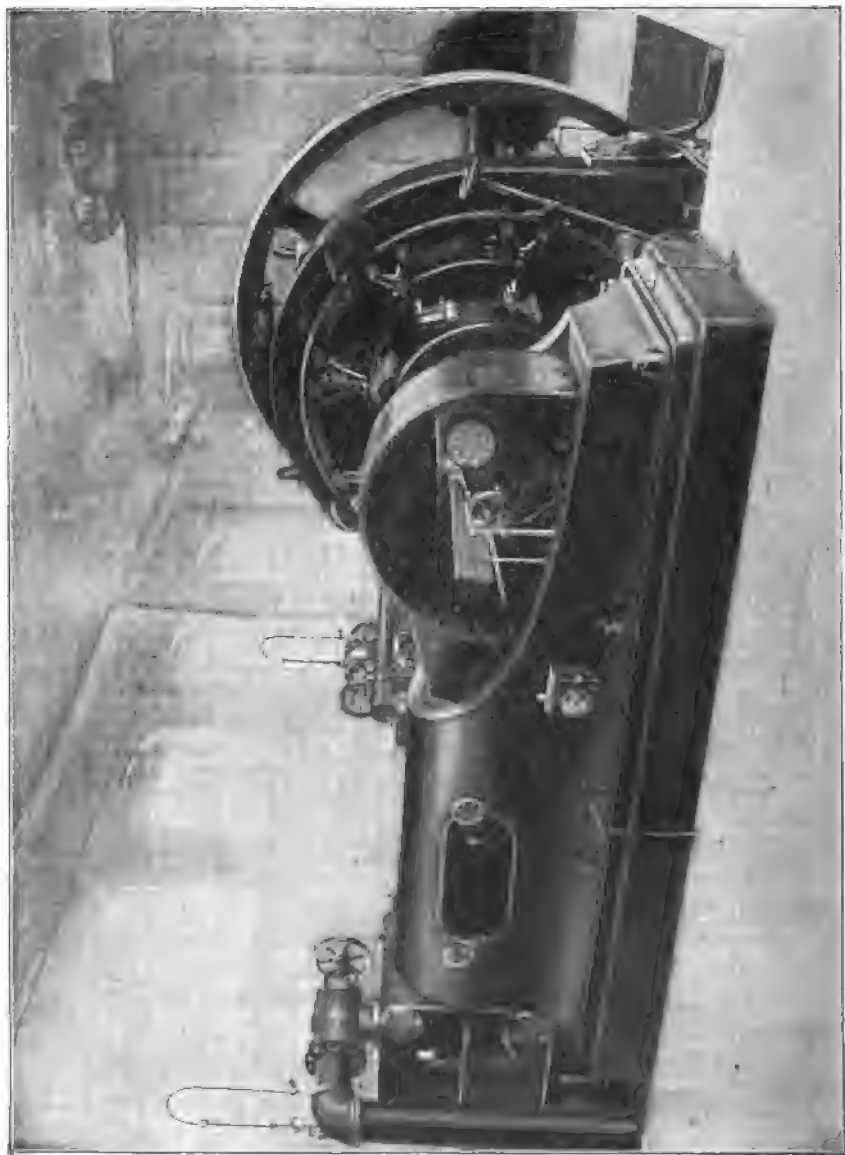
The first requisite in the installation of a dynamo, is to have a good foundation. With direct driven machines, the engine and dynamo should be mounted on the same bed-plate, whenever the size of the machine permits. Freedom from dampness and dust, as well as good ventilation should be carefully considered when selecting a location for a dynamo.

The dynamo should be placed far enough away from its driving pulley to allow the belt to have good contact, otherwise the belt will constantly slip, causing variations in the current, and when used for incandescent lighting, this will cause the lights to "wink."

The driving and driven shaft must be parallel, and the centers of the two pulleys in a line at right angles to the shaft.

Cleanliness.—The dynamo, as well as all electrical machinery, should be kept scrupulously clean, and the temperature of no part of the machine be allowed to rise so high as to make it uncomfortable to hold the hand against any part of the machine.

Operation.—The dynamo armature should be turned over slowly before starting, noting if it turns easily and if the brushes make proper contact at all parts of the revolution. The speed should be very **gradually** increased on starting up, so that any faults which may develop, can at once be remedied before any damage results.



A Western Electric 300 K. W. Generator, 250 Volts, 120 R. P. M.
Fig. 247.

Motor.—Before throwing the main switch for starting a motor, the starting resistance must always be included in the armature circuit. This should be gradually cut out as the motor comes up to speed.

Stopping.—In stopping a dynamo or motor, never throw any switch carrying a heavy current, but the machine should be allowed to gradually come to a stop, and not until then should the main switch be opened.

Brushes.—The position of the brushes should be such that the machine runs absolutely without sparks, and when a change of load causes sparking, the brushes should be at once shifted to the right position, as the commutator will become cut and so roughened if allowed to run long in this condition that it will soon have to be turned down with a cutting tool.

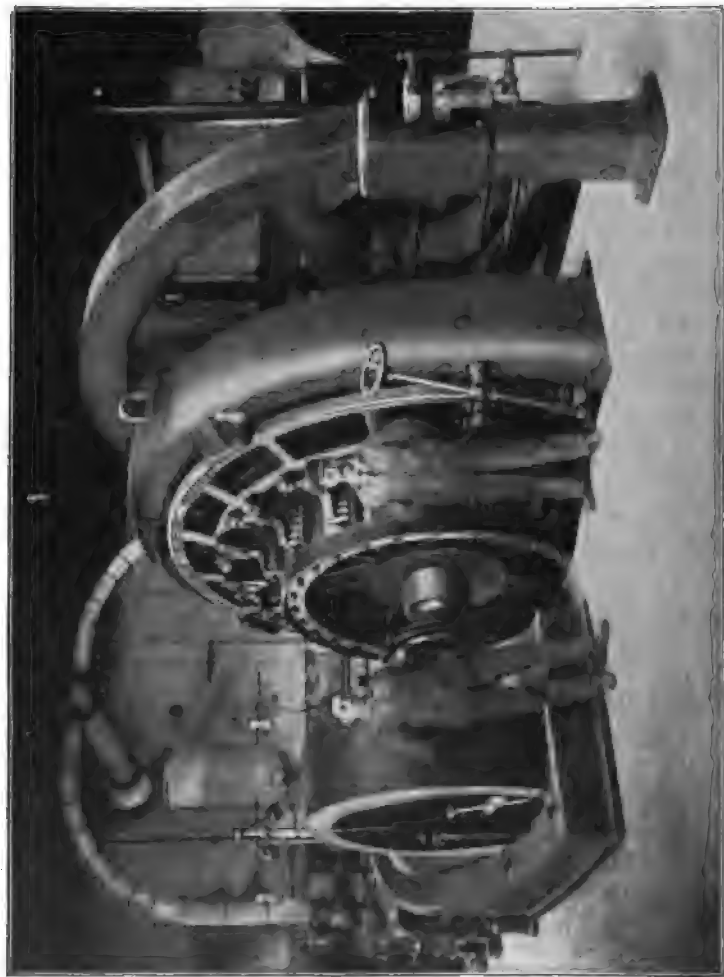
Causes of Sparking.—Sparking of the brushes may take the form of a vivid flash of light that hovers around the point of contact, or it may be intermittent.

There are a great many causes for sparking, the principal ones being as follows, viz.:

(1) Overload. (2) Brushes improperly set. (3) Brushes making improper contact. (4) Commutator rough or uneven. (5) Belt slipping. (6) Short circuit or reversed armature coil. (7) Too high speed. (8) High resistance of brushes. (9) Dirty brushes or commutator. (10) Vibration. (11) Worn commutator. (12) Grounds.

Failure of Dynamos to Generate.—This is due to insufficient residual magnetism in the field magnets. It only occurs when the dynamo is a new one, or when the field magnets have been taken apart for repairs. It seldom or ever occurs if the field magnets are cast iron.

Remedy.—It may be remedied by passing the current from a few storage cells for some time in the proper



A Western Electric 800 K. W. Generator, 250 Volts, 80 R. P. M.
Fig. 248.

direction through the **field coils**, but in practical work it is usual to charge the fields from an outside source. If the dynamo is run in multiple with another dynamo, it is only necessary to **lift** the brushes and throw in the main line switch, the same as is done to cut the machine into service. The fields in this way take a charge from the line, and their **polarity** will then be correct; that is, it will be the same as that of the other machine.

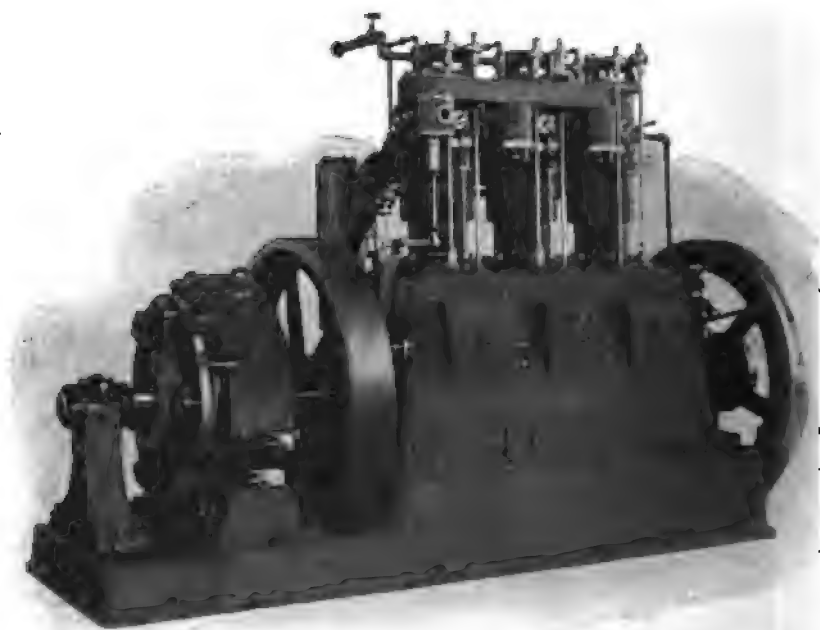
Failure to generate is also caused by the wrong **connection** of field or armature; from **open circuits** or **short circuits**, or from the field coils being incorrectly connected so that they **oppose** each other, thereby causing a **reversal** of the magnetism of polarity.

Under such conditions, the field coils produce a polarity opposed to the magnetism to which they owe their energy or strength, and therefore the machine will refuse to generate until the field connections are reversed; that is, the **polarity** in the pole pieces is corrected by sending a current from another machine through the field coils in the **proper** direction.

Alternating Current Machinery.—We have seen from Fig. 220 that when a coil is rotated within a magnetic field, that the opposite sides of the coil assist each other in the generation of an electrical pressure, and that therefore the E. M. F. is **double** that produced by a single conductor or rod.

By the operation of the coil rotated as shown, an alternating current is produced, and the apparatus for producing such a current is the simplest form of an alternating current machine, or alternator, as such a machine is usually called.

Essential Parts.—The coil is mounted so as to rotate between the north and south poles of a magnet. The ends of the coil are connected to two copper connecting



A Western Electric 40 K. W. 125 Volt Generator Direct Connected to Gas Engine, Speed 290 R. P. M.

Fig. 249.

rings mounted on the shaft with the coil, but insulated from it. Upon each of these rings presses a stationary brush, which is kept always in contact with the rings and serves to **conduct** the current to an outside circuit.

Circuit.—A complete circuit is thus furnished from one brush through the external circuit to the other brush, where the collecting ring transmits it by means of its brush through the coil back to the first brush; and in this way the current continues to flow around this circuit as long as the coil is rotated.

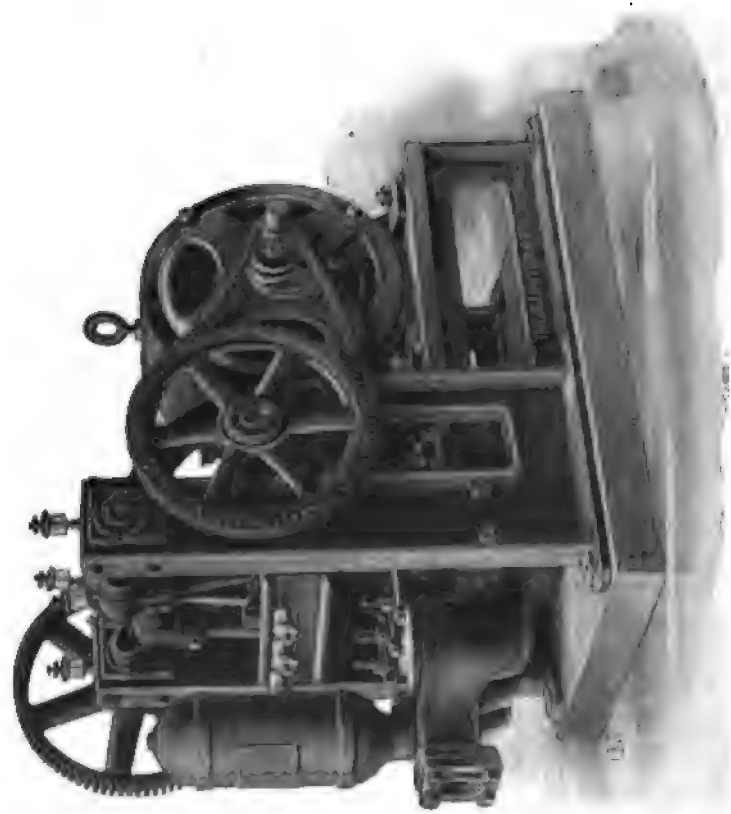
The alternating current produced by the rotation of the coil flows out to the external circuit in one direction during **one-half revolution** of the coil, but in an **opposite** direction during the remaining half of the revolution; and such flow of the current continues back and forth during each revolution of the coil.

The **strength** of the current rises and falls with these changes in the current, being greatest when the coil cuts the lines of force at right angles, which is when it lies in a horizontal plane, and is less when moving parallel with the lines of force, which is when it is in, or near, a vertical position.

Cycle.—These series of changes in a current, as is represented by the diagrams in Fig. 221 and 222, are called **cycles** or **periods**, and represent the current's strength, or E. M. F., during each complete revolution of a single coil in a bipolar field, i. e., a field having two poles.

In Fig. 221 (2) is represented **one** cycle, it being one complete revolution of the coil.

Alternation.—An alternation represents the change in a current during one-half of each revolution of the coil, and therefore **one** cycle is composed of **two** alternations.



The Aldrich Electric Boiler Feed Pump.
Fig. 250.

Frequency.—The number of cycles occurring per second is designated as the **frequency**, and is equal to the number of revolutions per second of a single coil in a bipolar field. For instance, if the coil makes 1800 revolutions per minute, the **frequency** will be 30 cycles per second, which is usually designated as simply 30.

As each coil or conductor on the armature will pass through as many fields in each revolution as there are pairs of poles on the machine, the frequency of an alternator is therefore obtained by multiplying the number of revolutions per second by the number of pair of poles. For instance, an alternator having 10 pair of poles and making 900 revolutions per minute, will have a frequency

$$\text{equal to } \frac{900}{60} \times 10 = 150.$$

In Fig. 222 (1) is shown **two** separate coils placed in a magnetic field at right angles to each other. Instead of the commutator now being made in **two** halves or segments, it is composed of **four** segments, the two ends of each coil being connected to opposite segments. These segments must be insulated from each other so as not to **short-circuit**, and the two metallic brushes continue to press against the segments as before, they being at all times in contact with **two** segments diametrically **opposite** to each other, instead of with only **one** segment, as when but one coil of wire was used.

These brushes are connected to the **external** circuit the same as was done when only one coil was used.

In Fig. 222 (2) is shown a diagram of the fluctuations of the current when **two** coils are used. In this diagram the current produced by each coil is represented by a curve, making **two** curves in the diagram instead of only one curve as shown in Fig. 221 (2).

It is seen from this that the **greater** the number of coils used, the **stronger** and more **uniform** becomes the current, so that by using a sufficient number of coils, the current can be made almost continuous. A continuous current of uniform strength is known as a **constant current**.

In such a current, the pulsations in the flow become almost unnoticeable, and it is therefore especially **desirable** for incandescent lighting and other work requiring a perfectly steady current.

It is therefore seen that a current when first produced by a dynamo or generator is an **alternating current**, the alternations extending back and forth over the entire circuit, and amounting to many thousand in a second

For incandescent lighting there should be at least a frequency of as much as 45 cycles per second, otherwise it will cause a **winking** in the lamps.

It has been further seen that in order to send the current out as a **direct current**, in which current the flow is always in the **same** direction, it is necessary that the current be changed upon the machine **before** transmission.

The addition of a **commutator** is required to make this change, and this practically is the **only** difference between a direct and an alternating current dynamo or generator.

Dynamo or Generator.—The word dynamo is derived from a Greek word, meaning **power**, while the word generator is derived from a word meaning **birth giving**, and hence the two names are used interchangeably for electrical machines, though we usually speak of a dynamo when the current produced is to be used for **lighting**,

and generator when the current is to be used for **power** purposes in operating motors.

Neither of these electrical machines **generate** electricity, but they only create the **pressure** to make it available for power; as with air and water from which neither power nor work can be obtained without pressure. In the same way we cannot get the flow of an electric current with the accompanying electrical energy without **pressure**, and this pressure must be supplied by one or the other of these electrical machines.

Contruction of the Armature.—The coil of wire shown in Fig. 220 and Fig. 221, is the simplest possible form of an armature, and its revolution between the magnets as has been shown, is the simplest form of a dynamo or generator. The larger the number of loops the greater the electrical energy gathered by the armature and sent out over the circuit. The **strength** of the current also depends upon the **amount** of magnetism in the field coils, which take the place of the permanent magnet shown in the illustrations. These field coils with the **iron core** about which they are wound, are nothing more than an electro-magnet, the construction and operation of which has already been described.

When the machine is first started up, that is the coil made to rotate, there is only what is known as the residual or natural magnetism in the iron, and therefore there are but few lines of force emanating from it, and the current which is generated is therefore very slight.

As, however, the loop, or loops when more than one is used, passes through this magnetic field, it gathers a small amount of electrical energy, which is made to pass through insulated wires wound around the magnetic cores or pole pieces composing the fields, which at once strengthened the magnetism of the field, and this in turn

produces a greater electrical energy within the armature, which greater energy is again utilized to strengthen the influence of the magnet, and in this manner the machine is built up to its full capacity.

The armature is made up of a **number** of such coils wound about a soft iron core which serves to conduct the magnetic lines, all the coils being interconnected by means of the commutator which forms a part of the armature.

The armature is wound in a great number of ways, but the **drum** armature is the armature most generally used on account of its simplicity and comparative efficiency.

Drum Armature.—Such a type of an armature is shown in Fig. 223 and also Fig. 229. It will be seen in Fig. 229 that the wires are wound longitudinally, that is lengthwise, upon the cylinder or drum, and each loop of wire connected to the commutator as shown in Fig. 231.

The armature core is made up of sheet iron discs, these discs being insulated from each other, usually by a thin sheet of paper or other non-conducting material, in order to prevent the current from being **short circuited**, that is, instead of traveling the entire length of each loop, the current will jump across and take the shortest path from one connection to the other.

The circumference of these discs are provided with apertures for holding the armature coils in place. These apertures are shown in Fig. 229, which illustrates an armature in process of being wound.

Eddy Currents.—When an armature rotates in a magnetic field, the magnetism of its core is constantly **changing** as its parts pass through the different magnetic planes surrounding the poles.

When opposite a pole, the magnetism is at a mini-

mum, as that part of the armature is moving parallel with the lines of force and hence no magnetism is generated; but when the coils are moving at right angles to the lines of force, the magnetism is then at its maximum, but the lines then pass through the core in an **opposite** direction.

All parts of an armature core are therefore being continually magnetized in one direction, and then **demagnetized** as the parts pass into the opposite plane or magnetic field, and then magnetized again as the armature continues to rotate.

This magnetizing and demagnetizing of the armature as it passes each pole, continues as long as it rotates.

The loss resulting from the constant changes in the lines of force through the armature core is called **hysteresis**, which is from a Greek word meaning, "to lag behind."

This lagging behind of the lines of force is caused from their **opposition** to the changing of their direction of flow, that is, their tendency is to **maintain** any magnetic state which they have once acquired.

This constant changing of the direction of the lines of force, produces what is known as **eddy currents** in any solid mass of metal which is rotated in a magnetic field, or which is subjected to a **varying magnetic** field.

Such currents tend to flow in a circular path, and when produced in a large solid body they are very objectionable, as they not only consume a large amount of **energy**, but they also frequently cause a dangerous rise in the **temperature**, which may burn out the armature coils.

Prevention.—While it is impossible to entirely prevent the generation of these eddy currents, they can,

however, be prevented from attaining any considerable strength.

This is done by making the **core** of the armature **laminated**, that is, divided into a large number of thin sheets, each sheet being insulated from the other by some insulating material.

Armature cores are usually constructed, or **built up** as it is called, of thin sheet iron discs, as shown in Fig. 228, which discs are stamped out from soft sheet iron. These discs are insulated from each other usually by covering one face with varnished paper, or both faces are enameled.

Field Magnets.—Cast iron, cast steel and wrought iron are the principal materials used in the construction of the field magnets. These three metals have a very high **permeability**, by which is meant the conductivity for magnetic lines of force, or a measure of **ease** with which magnetism passes through any substance.

Saturation.—A metal can be **saturated** with magnetism the same as a sponge is saturated with a liquid. In good iron the point of saturation is about 125,000 lines of force to the square inch of area of cross section, that is, that much area will absorb only that much magnetism.

When cast iron is used in the construction of field magnets only about 45,000 lines of force to the square inch is allowed, while for wrought iron as much as 90,000 lines of force are allowed for this area. Therefore, when a small cross-section of core is desired, wrought iron is used, as its high permeability requires less cross-section area.

For convenience in handling, field coils are usually wound on a separate form or spool, as shown in Fig. 226, and these spools then placed on the cores or pole pieces.

Ampere-Turns.—These windings of the wire upon the cast iron, wrought iron or cast steel field frames, are called **turns**, and the amount of magnetism produced in the fields by the passage of a current through these turns, depends upon the **number** of turns, and the **strength** of the current passing through them. Therefore, the product of the number of turns and the strength of the current passing through them expressed in amperes, is called the **ampere-turn**.

So far as the amount of magnetism is concerned, it is immaterial how the number of turns and the strength of the current are proportioned, as long as the product is the same.

That is, it makes no difference whether there are 10 turns with 3 amperes, or 15 turns with 2 amperes, as the product is 30 ampere-turns in each case.

Virtual E. M. F.—As the E. M. F. of an alternating current continually varies, rising and falling and reversing its direction, there must be taken some **fixed unit** as a standard measure to obtain its strength. As the E. M. F. is equally effected in one direction as the other, its value is therefore **independent** of the direction of the current, and the current can be regarded as acting in only **one** direction in determining this standard of measurement.

No such trouble is experienced in finding the E. M. F. of a **direct current**, as it is a constant current and does not vary. Therefore, the alternating current must be measured by comparison with the direct E. M. F. and the direct current. An alternating E. M. F. or current, which produces the same deflection on an electrostatic voltmeter as produced by a direct E. M. F.; and an alternating current which produces the same **heating effect**

as a direct current, have the same value, and which value is known as the virtual E. M. F. and current.

This **virtual** value is equal to .707 of the **maximum** value. Therefore, an alternating E. M. F. having a maximum value of 150 volts, would have a **virtual** value only of $150 \times .707 = 106$ volts, or a current having a maximum value of 60 amperes, has only a virtual value of $60 \times .707 = 42.4$ amperes.

Self-Induction.—When a current flows through a wire, the wire becomes at once **surrounded** by whirls of magnetic lines, such as is shown in Fig. 218.

We have seen that by **coiling** the wire, this effect is greatly increased, and by supplying the coil with a soft iron core which acts as an electro-magnet, the effect is further greatly increased. But this self-induction in an alternating current tends to **restrain** the current when it is increasing, and in consequence prevents the current from obtaining its full strength.

The greater the amount of this self-induction in the circuit, the more is the strength of the current reduced. The effect of self-induction on an alternating current is therefore to **increase** the **apparent resistance**, and therefore requiring a greater E. M. F. at the terminals of the circuit than in the case with a non-inductive circuit.

This additional resistance of the circuit due to self-induction, is called **reactance** to distinguish it from the ohmic resistance of the conductor.

The combined effect of the reactance and the ohmic resistance, is called **impedance**.

In order, therefore, to find the value of an alternating current, the applied E. M. F. must be divided by the impedance of the circuit.

Now, when **two** coils are placed so that the magnetic whirl, or flux as it is called, of one coil passes

through the other coil, an E. M. F. is induced in the latter coil.

This requires the current in the first coil to vary or alternate, as is always the case when an alternating current is used.

If the coils are supplied with an **iron core**, the reluctance of the magnetic current through the coils will be very much reduced, and in consequence the flux will be much increased, thereby greatly increasing the **efficiency** of the apparatus.

It is alone upon this principle a transformer is constructed, which apparatus is nothing more than an induction coil.

Transformer.—When an alternating current is used in one wire, it induces a current in an **adjacent** wire. This induction, however, takes place only during the period of an increase or decrease in the intensity of the current.

The coil to which the original energy is supplied is called the **primary** coil, while that in which the current is induced is called the secondary coil. On page 751 is shown the ordinary construction of a transformer.

The type of transformer here shown is what is known as the **Ruhmkoff coil**, and is intended to give a current of greater potential or higher voltage in the secondary coil than exists in the primary. It is what is technically called a **step-up** transformer, that is, one by which the voltage from the primary to the secondary current, is **increased**, the latter having more turns of wire.

Essential Parts of Transformers.—A transformer may be said to consist merely of a coil of wire placed within and carefully insulated from another coil. Within the inner coil there is a soft iron core, similar to that of an electro-magnet. In the practical transformer, this

core is made up of a number of plates or wires, and the entire apparatus is usually inclosed in a water proof case, in order that it may be placed out of doors so as to obviate the necessity for carrying the high tensile currents into a building.

Application of Transformers.—Next in importance to the discovery and utilization by Faraday of the lines of force for the production of an electric current, was the application of the induced current for the transmission with safety and through great distances of an electric current.

We have seen that the resistance of a circuit, or wire, to the passage of an electric current **increases** with its length, and that long lines require a stronger battery or current for their operation than do short ones. This increased resistance of long lines is one of the great obstacles to be overcome in the conveyance of an electric current over great distances. If the current is of low voltage, it does not have sufficient intensity to overcome the resistance of the line unless the resistance is made very low; and this low resistance cannot be obtained unless the wires are made very **large**. As these wires, or conductors, are usually made of copper, the excessive **cost** for such large wires would make their adoption impossible for practical purposes.

The other alternative for long distance transmission is the use of a **small** wire and a **high** voltage, but these high voltages cannot be used in ordinary electrical work as they are extremely dangerous, both from the standpoint of safety and danger from fires.

The means employed to overcome both of these serious difficulties is to use a small wire for the transmission of the current at an excessively high voltage, and then, at the point of utilization, insert a **transformer**

in the circuit, by means of which the voltage can be greatly **decreased**, so that it can be used with **safety**, and at **moderate** cost for any character of electrical work.

Should it be desired to send out a current of low voltage, and greatly increase it at the point of utilization, a **step-up** transformer as it is called, is used. On the contrary should it be desired to send out a current of high voltage and decrease it so as to be handled with safety inside of buildings, a **step-down** transformer is then used.

The principle upon which these two types of transformers act, is practically the same. The Ruhmkoff coils as above described is a type of the so-called step-up transformer. The only difference in their construction is in the winding of the primary and secondary coils.

Multiphase Alternators.—An alternator which supplies only a **single** current to the external circuit is known as a **single phase** machine, while one supplying **two** or **three** currents is known respectively as a two and three-phase alternator, or **polyphase** or **multiphase** machine.

Two-Phase Alternators.—The number of currents so supplied to the external circuit, depends entirely upon the **armature** windings.

With a single phase machine, only about **one-half** of the surface of the armature is wound. Should an additional winding be placed on the armature in the space left vacant, then **two** separate and distinct currents can be supplied over the same circuit at the same time, and the alternator is then designated as a **two-phase** machine.

This additional winding between the original coils, generates a **maximum** E. M. F. when the other coils are not cutting the lines of force, and hence their E. M. F. is zero, but when these windings are at their maximum, then the added windings are at zero.

In Fig. 222 is shown the phase relation of the currents supplied by their two externals and independent circuits. The curve 1, represents the value of the current given by one armature circuit, and curve 2 represents that given by the other circuit.

In a two-phase alternator, when the circuits are independent, there must therefore be four external wires and four collecting rings.

Three-Phase Alternators.—In the same way the armature may be made to supply three separate and distinct currents to the external circuit, all differing in phase, i. e., not in step.

When the windings are all independent of each other, six wires will be then required, but usually the three windings are combined so as to require only three external wires.

In Fig. 222 is shown the value of the two currents in armature windings, in which diagram 1 and 2 represent the two respective currents, while 3 represents their combination, or the actual curve produced.

Rheostat.—This is a resistance that can be varied at will, usually consisting of a resistance, such as coils of wire, with connections at short intervals, terminating in metal contacts arranged in a circle, such as is shown in Fig. 234.

On inserting this resistance, or rheostat, between the field coil, connecting it usually in the shunt winding and one of the brushes, the current in the field coil can be perfectly controlled, and thereby the voltage of the machine.

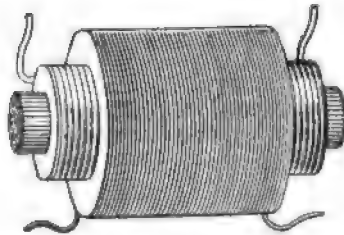
When the load increases and the effective voltage tends to drop, it is only necessary to cut out some of the resistance in the rheostat by moving the sliding contact piece, thus permitting more current to flow through the

field, increasing the magnetism, and thereby raising the voltage of the machine.

In this way the amount of resistance in series with the field can be perfectly regulated at all times.

Polarity.—By this is meant the possession of poles, of opposite properties, at opposite ends. This attraction and repulsion possessed by all poles of a magnet determines the direction of flow of the current and the flux. Hence, two or more electrical machines cannot be worked together unless their polarity is the same; otherwise they will resist each other.

Reversing Polarity.—The simplest way to change the polarity of a machine, is to raise the brushes and throw in the current from the other machine. The flow of the current through the fields, quickly reverses the polarity of this machine, thereby making the polarity of the two machines the same.



A Transformer.

H.P.		Per cent. of EM. ciency.	Watts.	16 C. P. 60 Watts lamps.	The top row indicates Volts.									
			50	75	110	220	400	500	600	800	1000	1200		
3/4	75	497	10	6.62	4.5	2.25	1.24	1	.88	.62	.497	.41		
1	75	716	14.9	9.94	6.78	3.38	1.86	1.48	1.24	.93	.716	.62		
1 1/4	75	995	20	13.24	9	4.5	2.5	2	1.66	1.24	1	.82		
2	80	1492	29.8	19.8	13.56	6.78	3.73	2.98	2.48	1.86	1.492	1.24		
3	80	1865	37.3	24.9	16.9	8.5	4.7	3.8	3.1	2.33	1.9	1.6		
4	80	2797	55.9	37.2	25.4	12.7	6.90	5.59	4.66	3.49	2.797	2.33		
5	80	3730	74.5	49.8	33.8	16.9	9.3	7.5	6.2	4.66	3.8	3.1		
6	80	4662	98.2	62.1	42.3	21.1	11.65	9.32	7.77	5.82	4.662	3.88		
7 1/4	90	6217	124	82.9	56.5	32.2	15.34	12.43	10.86	7.77	6.217	5.18		
10	90	8268	165	110	73.3	37.6	20.72	16.57	14.83	10.86	8.268	6.9		
15	90	12438	248	165	113	56.5	31.08	24.86	20.72	15.34	12.438	10.86		
20	90	16578	331	221	150	75.3	41.44	33.13	27.63	20.72	16.57	13.96		
25	90	20722	414	276	188	94.1	51.8	41.6	34.5	25.9	20.7	17.2		
30	90	24866	497	331	226	113	62	49.7	41.4	31	24.8	20.7		
40	90	33155	663	442	301	130	82.8	66.3	51.8	41.4	31.1	27.6		
50	90	41444	828	532	376	156	103	82.8	69	51.8	41.4	34.5		
60	90	49733	994	638	452	226	124	99.4	82.8	60	49.7	41.4		
70	90	58022	1160	773	527	263	145	116	96.7	72.5	58	48.3		
80	90	66311	1325	884	602	301	166	132	110	82.9	66.3	55.2		
90	90	74599	1491	994	678	339	188	149	124	96	74.5	62		
100	90	82888	1657	1106	758	376	207	166	138	108	82.8	69		
120	90	99459	1989	1326	904	452	248	198	165	124	99	82.8		
150	90	24312	2486	1657	1131	565	310	248	207	156	124	108		

Amperes per Motor.
Table No. 19.

Electric Light Conductors.

BROWN & SHARPE	DIAMETER.	SOURCE OF DIAMETER.	SECTIONAL AREA.	SAFE CARRYING CAPACITY IN AMPERES.				WEIGHT.		LENGTH.		RESISTANCE OF PURE COPPER WIRE AT 75 DEGREES F. (12.90 DEG. CENT.)			
				National Code.	New England Code.	Coastal Work.	Chicago Code.	BARE.		WEATHER-PROOF IN INSULATION.	Feet per Pound.	Ounces per 1,000 Feet.	Ounces per Mile.	Feet per Ohm.	Ounces per Pound.
								Pounds per 1,000 Feet.	Pounds per Mile.						
No.	Mils.	Millimetres.	Circular Mils.	Squares	Circular Mils.	Squares	Circular Mils.	Pounds per 1,000 Feet.	Pounds per Mile.	Feet per Pound.	Ounces per 1,000 Feet.	Ounces per Mile.	Feet per Ohm.	Ounces per Pound.	Ounces per Pound.
0000	400	0.011	64	21400	0.07	319	175	3002	1812	639	758	4000	1.25	25403	.00076738
000	400	0.010	405	17800	0.56	088	145	245	181	2007	404	3300	1.75	.38944	.00012089
00	364	800	9.366	138079	4	67	431	180	315	160	402	04112	2	.07801	.00019433
0	334	900	8.354	105502	5	53	504	100	190	125	185	319	04	.51909	.00030772
1	299	300	7.248	83694	2	43	409	95	160	105	154	232	88	.03480	.00044694
2	267	600	6.544	66373	0	33	032	70	135	88	131	200	54	.62952	.00073945
3	239	425	5.827	53634	0	26	670	60	115	75	110	239	08	.19723	.00129408
4	204	310	5.169	41742	0	21	181	50	100	63	92	126	12	.24809	.00197321
5	181	940	4.621	33108	0	16	778	45	90	53	77	100	10	.31261	.003181361
6	162	680	4.115	28550	5	13	301	35	80	45	65	79	22	.38540	.00438968
7	144	290	3.693	20816	0	10	545	30	67	33	62	50	330	.49871	.0073934
8	128	400	3.264	16509	0	8	396	25	60	23	46	49	50	.63861	.0129035
9	144	430	2.907	13044	0	6	635	20	50	19	39	56	308	.76881	.0200048
10	101	960	2.586	9234	0	5	390	20	40	25	33	31	37	1	.82200
11	90	742	2.305	8234	0	4	172	17	35	11	24	86	131	1.2607	.030692
12	80	608	2.033	6890	9	3	309	15	30	17	23	19	73	1.5398	.043945
13	71	931	1.832	5178	4	2	616	15	25	15	15	16	64	2.047	.07682
14	64	084	1.665	4108	8	2	031	10	22	16	12	14	65	2.6406	.12641
15	57	086	1.450	3356	7	1	620	7	18	11	9	84	51	3.1150	.21668
16	50	580	1.291	2648	9	1	306	6	15	7	81	41	18	4.0191	.31801

Table No. 20.

CHAPTER XXVII.

ELEVATORS.

Definition.—The term elevator is applied to that class of hoisting machinery used to raise and lower a cage, car, platform, etc., between fixed landings.

In many foreign countries they are designated as “lifts.”

Principal Parts.—The following are their principal parts: (1) The motor. (2) The car, cab, etc., with guides and counterbalance weights. (3) The transmission device. (4) The controlling devices. (5) The safety devices.

Classification.—The classification of elevators is made according to the motive power used for their operation, the most common classes, or types, being hand power elevators, steam elevators, belt elevators, hydraulic elevators and electric elevators.

Counterbalancing Weights.—In all elevators, regardless of the type, the weight of the car is **counterbalanced**, so that its entire weight and fixtures is not a dead weight, but only the **difference** between the weight of the car and the counterweight.

It is usual to attach the counterweight to the car by means of a separate rope which is lead over one or more overhead sheaves.

The counterweight must be **lighter** than the weight of the empty car and fixtures, so that the car may descend when empty by its own weight, and the power necessary to raise the car must then be only sufficient to raise the load, plus the **unbalanced** weight.

Overbalanced.—When the power must be applied during **both** the up and the down trip, the car is said to be **overbalanced**. This is usually done in all **drum** ele-

vators, they being made with the motor and drum **reversible**.

Counterweights.—These are generally made of cast-iron blocks, carried in a frame and guided by suitable guideways. The guides are usually made of T iron, though wood is sometimes used.

Chains.—To avoid the extra weight of ropes in high buildings, balancing chains are often used, which are hung from the bottom of the car.

Controlling Devices.—Such devices consist essentially of some form of **power** control, as a **wheel** or **lever**, and a **brake**. The **shipper rope** which passes through the car and is connected to the controlling motor, is the simplest form of motor control. As a delicate adjustment cannot be obtained with such a control, and as such a rope is also dangerous from any broken strands which may catch in the passage of the rope through the hand of the operator, this form of control is not now generally used.

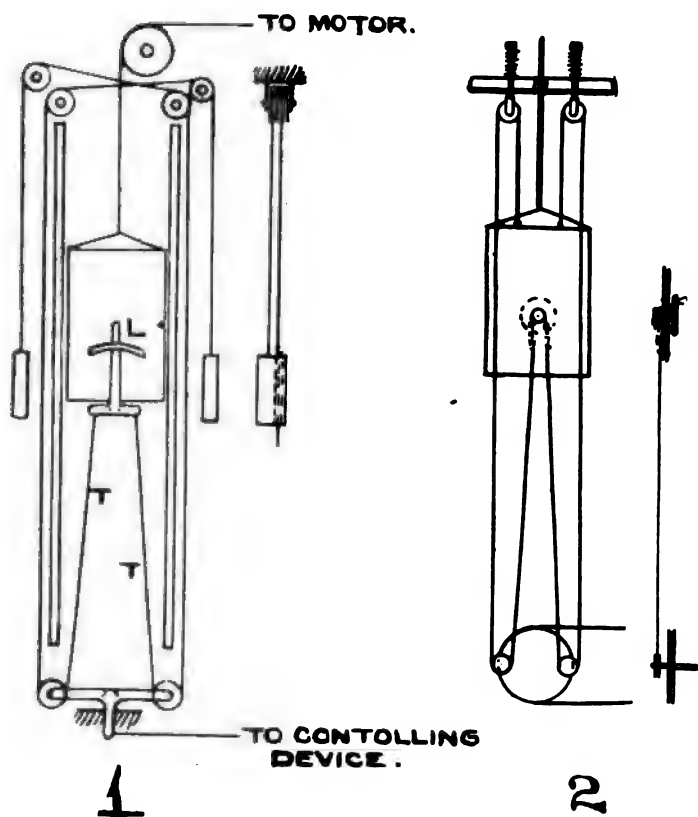
In order to overcome these objections various devices are used for changing the motion of a shipper rope into the motion of a lever or crank.

In Fig. 251 is shown two of the most generally used control devices.

In the arrangement shown in (1) there is a three-arm lever L in the car, the long arm of which is moved to the right or left by the operator, according as he desires the car to go up or down.

To each of the shorter arms is connected a rope T running down and over an idler carried by another three-arm lever R, which is pivoted at the bottom of the hoistway. The arrangement and operation of the ropes can be clearly seen from the diagram.

The arrangement shown in (2) is the usual oper-



Elevator Control Devices.
Fig. 251.

ating device employed by the Otis Elevator Company on their hydraulic lifts.

In this arrangement it will be noticed a **hand-wheel** is substituted for the lever. Such a device is called a **hand-wheel controller**, while the control shown in the first diagram, is known as **lever-controllers**.

Electric Controllers.—Such controllers consist of combinations of switches and resistances, and while they serve the same purpose as the mechanical controllers above described, their operation is altogether different as will be seen from their description hereafter given.

Safety Devices.—Such devices are usually divided into **two** classes, viz.: (1) Those that control the **motive power** itself, which are called Motor Safeties, and (2) Those that control the operation of the car, which are called **Car Safeties**.

Limit Stops.—The most generally used safety device of the first class, or motor safeties, is the **limit stop**. This consists of two knobs, or buttons, so placed on the shipper rope that should the operator fail to stop the car when the car reaches the limit of its travel, it will strike against one of these knobs, or buttons, and thus automatically operate the **shipper sheave**, thereby stopping the car before doing any damage. These buttons are placed **both** at the top and bottom limit of the travel of the car, so as to shut off the power should the operator fail to do so, either in going up or coming down with the car.

Owing to liability of these buttons slipping or breaking, they are no longer relied upon for safety, but are only used as an additional precaution to the limit stop which is placed on the motor itself.

Limit Stops on Motors.—For drum elevators, the limit stops are usually constructed as follows: A screw

thread is cut on a continuation of the drum shaft, and a gear-wheel, the hub of which forms a nut, is placed on the threaded portion of the shaft. This gear-wheel meshes with another gear-wheel bolted to the shipper sheave. The hub of the wheel has claws on either side, corresponding to similar claws formed on two other nuts that are clamped securely to the drum shaft.

When the wheel travels either way, it will eventually be engaged by one or the other of the revolving nuts and be swung around carrying with it the shipper sheave, with the effect of cutting off the power and applying the brake.

Slack Cable Safety.—It often happens that the elevator car is obstructed in its descent by gummy guides, or the car is hastily stopped by the operator, causing the cable to continue to pay out as the motor continues to run.

This may permit the car to drop; or should it be resting on the bottom of the hoistway, the slack cable may cause considerable damage by getting into the revolving parts of the machine.

To provide against such an emergency, elevators are generally equipped with a safety device called a **slack cable safety**.

Such a device consists of an idler which travels axially on its shaft with the hoisting rope along the drum. The shaft is supported on levers which are pivoted in a convenient manner. A cord leads from the arm of the lever over sheaves to a bell-crank, one arm of which is weighted, while the other engages a clutch. As long as the hoisting rope is taut, the idler is pushed outward against the weight of the bell-crank; but should the hoisting rope become **slack**, the weight on the bell-crank will cause the clutch to engage the gear-wheel mounted

loosely on the drum shaft, causing the same to revolve with the drum shaft. The gear-wheel meshes with another gear-wheel fastened to the shipper sheave, turning the latter around as the hoisting cable becomes slack, and in this way the power is cut off by the stopping of the motor.

Legislation.—Owing to the great height of modern buildings, and the high speed with which passenger elevators must be run, there should be a **monthly** inspection made of all passenger elevators, and especially of all **safety devices** on same.

To insure such an inspection, the owner of the elevator should be required to have the same made by a duly authorized official, under a heavy penalty for failure to do so.

Belt Elevators.—Such elevators are driven directly from **line-shafting**. They are therefore generally used only for **freight service**.

Steam Elevators.—Until recently this was the most popular type of elevator owing to its reliability and efficiency. It still is favored by many users, though it is hardly probable that it will ever be adapted to the constantly increasing modern requirements.

Construction.—The engines used for their operation, are duplex engines of the vertical type.

Both the slide valve and piston valve are used by manufacturers, but the slide valve is preferable. Owing to the necessity of prompt starting, stopping and reversing the engine, the engines are made duplex. The steam valve used is known as a **reversing valve**, the construction of which is fully shown in Fig. 252.

Steam Cylinder for Crane Reversing Engine.—Steam enters at D and fills the chest A. If the change valve E is moved to the position shown in Fig. 1 the

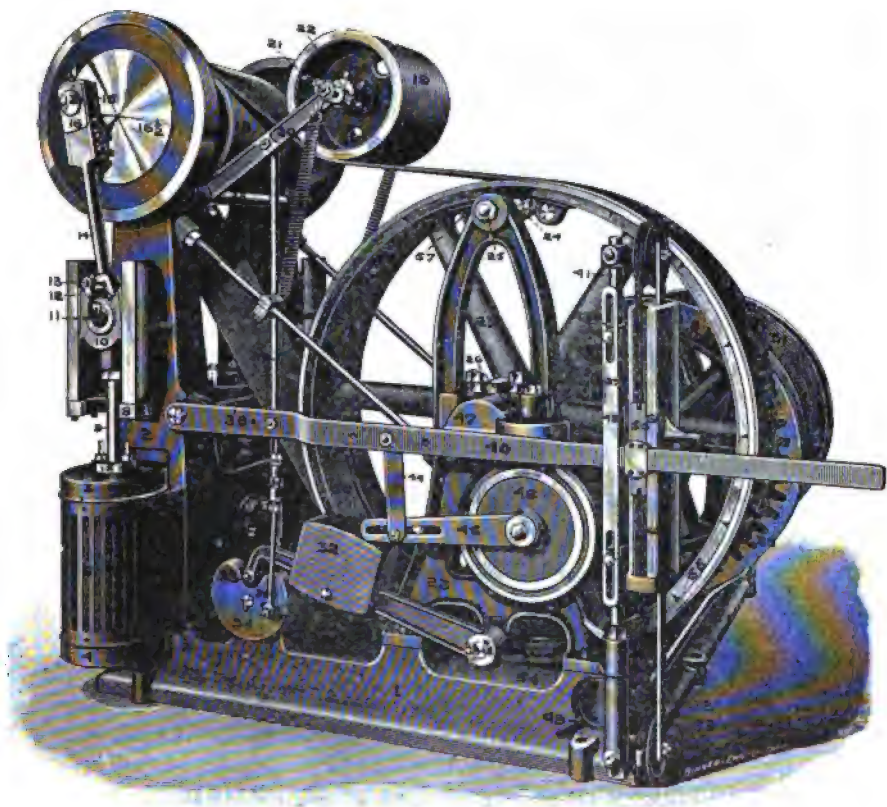
port C is opened, thus allowing steam to flow through the passage C to the cylinders. The steam is controlled by the slide valve F, which is operated through its connections by the main shaft of the engine. The exhaust steam from the cylinders passes out through the passages B into the exhaust pipe G.

To stop, the change valve E is moved to the position shown in Fig. 2, closing both passages B and C. To reverse the engine, the change valve E is moved to the position shown in Fig. 3. The passage B is opened, allowing steam to flow into the cylinders, being controlled as before by the slide valves F. The exhaust passes out through passages C into the exhaust pipe G.

Belted Steam Freight Elevator.—In Fig. 253 is shown a type of belted steam freight elevator, with its different parts, numbered as follows:

Parts.—

1. Bed.
2. Combination.
3. Ornamental open head.
4. Ornamental solid head.
5. Gland for cylinder head.
6. Curved lagging.
7. Straight lagging.
8. Guide or oil drips.
9. Piston rod.
10. Crosshead.
11. Crosshead pin.
12. Crosshead gibb or slipper.
23. Brake pulley stand.
24. Brake bolt.
25. Brake bolt, nut and washer.
26. Brake pulley stand cap.
27. Brake pulley.



A Belted Steam Freight Elevator.
Fig. 253.

- 28. Drum stand cap.
- 29. Driving pinion.
- 30. Internal gear.
- 31. Drum.
- 32. Brake weight.
- 33. Brake lever and roller.
- 34. Brake cam.
- 35. Right and left connection.
- 48. Automatic stop worm wheel and pinion shaft (covered).
- 49. Slack cable lever.
- 50. Slack cable lever link.
- 51. Slack cable reversible shaft.
- 52. Slack cable bracket for reversible shaft.
- 53. Slack cable, arms and slats.
- 54. Brake crank.
- 55. Brake blocks or wood.
- 56. Brake band.

The above parts are given for a fuller understanding of the automatics.

These elevators are usually **overbalanced** when made with **worm-gearing**, but like belt elevators are not overbalanced when made with **spur-gears**.

Hydraulic Elevators.—This is regarded as the most safe type of elevators, especially for high lifts and great speeds.

The simplest form is the direct acting or **plunger** elevator, but this form is not as generally used as the **piston** type of this elevator.

The most serious objection to the plunger elevator is the large amount of **space** required for its operation, and also the large **volume** of water required. This is due to the hydraulic cylinder and plunger having a length equal to the lift.

In the piston elevator, the hydraulic cylinder can be made much shorter by introducing multiplying sheaves.

Plunger Elevator.—The plunger elevator is conformable for either passenger or freight service and has a high degree of efficiency, due to the fact that the power is exerted direct without the intervention of sheaves or cables. The car is always supported from beneath by the plunger, and therefore there is no necessity for providing it with the safety appliances used on the car in other types of elevators. Owing to the fact that a cylinder of a length equal to the car travel must be sunk in the ground, the nature of the soil has a considerable bearing upon the cost of the installation.

For passenger service, plunger elevators are built with travels as high as 225 feet and with speeds as great as 600 feet per minute. For freight service, they are built with a lifting capacity up to 80,000 pounds.

Hydraulic Plunger Elevator.—The Otis Pulling Plunger Type of Hydraulic Elevator differs from any other in the respect that when **lifting** the load it does not consume water, but **discharges** it from the cylinder.

In this elevator the weight of the plunger itself, which is of solid steel, lifts the load, the plunger descending into the cylinder as the car rises in the hatchway. When the operation is reversed and the car descends, the water is pumped up to the required pressure and, assisted by the weight of the car, raises the plunger and the car descends.

This elevator was designed to meet the requirements of high buildings, and on account of its economy in operation, very high speed, and the extreme rapidity with which stops and starts can be made, ranks high among hydraulic elevators.

As this machine is operated under a medium pressure, rarely exceeding 250 pounds per square inch, it is possible to use the compression-tank system.

The compression tank is usually placed in the basement and the discharge tank either on the roof or in any convenient location at least as high as the top of the cylinder, so that the cylinder is always filled with water, thereby acting as a safety brake.

Piston Type.—There are two types of the piston elevator in general use, viz.: (1) The vertical, and (2) The horizontal type.

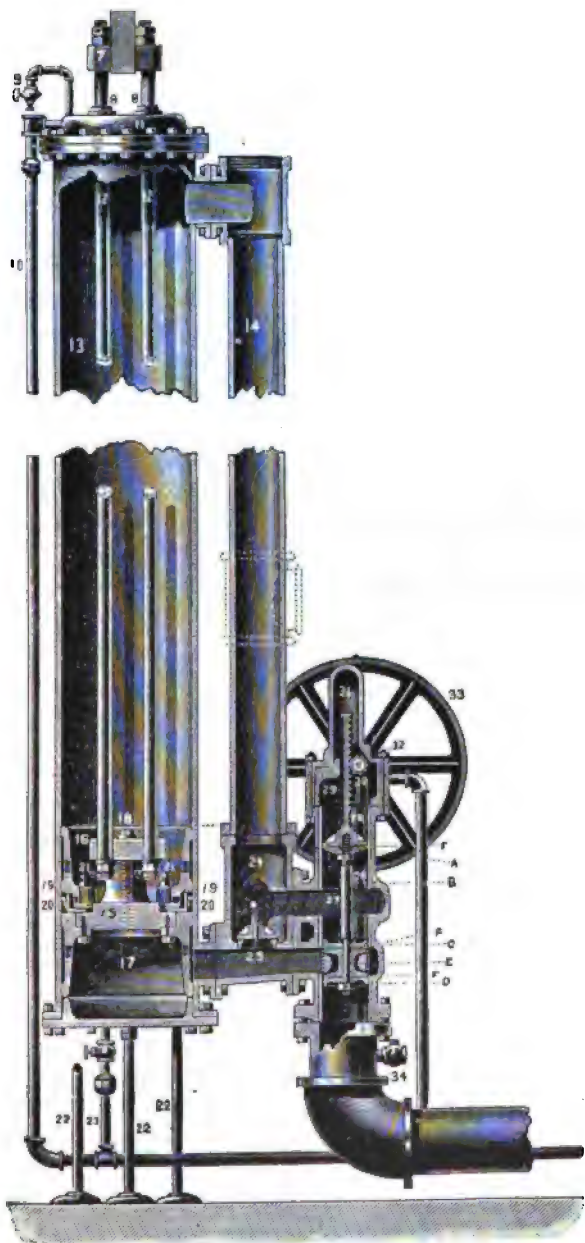
Vertical Hydraulic Piston Elevators.—Where space is limited, this is the preferable type as it is always easier to obtain head-room, than it is floor space.

Construction.—In Fig. 254 is shown the parts and general construction of this type of elevator.

Controlling Device.—The controlling device consists of a balanced three-way valve operated by a shipper rope in the usual manner.

The action of the motor under its control is as follows: The space of the cylinder above the piston is always under water pressure, the supply pipe being directly connected with a space through the circulating pipe. The other end of the circulating pipe is connected between the two valve pistons in the valve chamber. If the valve pistons be moved downwards, so as to bring the upper valve chamber, and in this way the space of the cylinder above the piston, into communication with the space below the piston, there will be the same water pressure on **both** sides of the piston.

Thereupon, the car being heavier than the piston with the counterweights, will cause the latter to ascend, while the car itself is descending, and by which operation the water from above the piston will be forced



The Otis Vertical Hydraulic Passenger and Freight Machine.
Fig. 254.

through the circulating pipe into the space under the piston. For the ascent of the car, the valve pistons are reversed so as to put the space of the cylinder **below** the piston into communication with the discharge pipe. This places all the pressure on the top of the piston, and as it descends it raises the car.

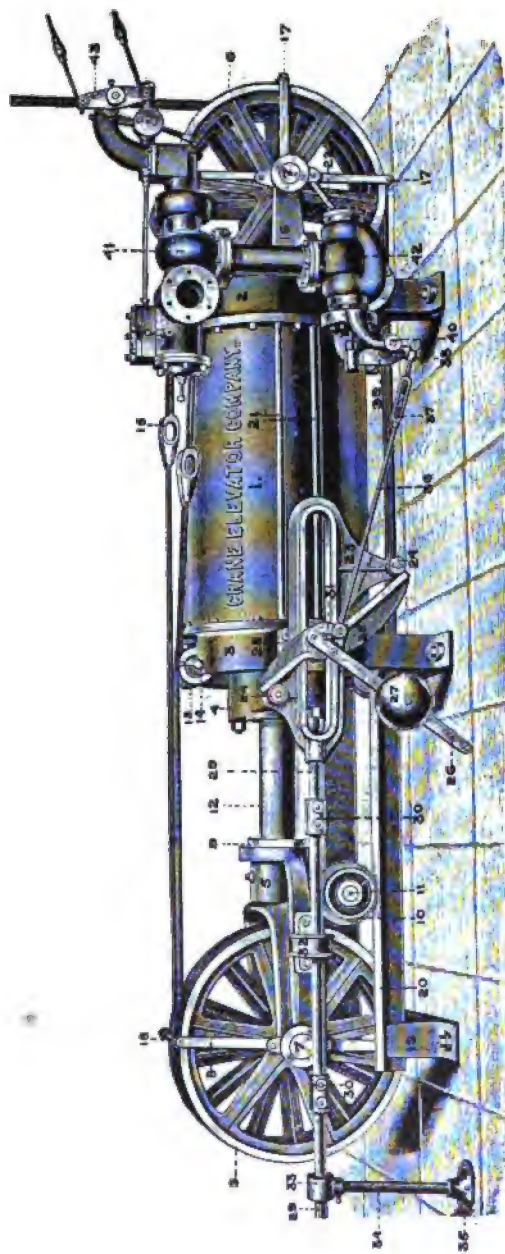
Pilot Valves.—Instead of using the ordinary relief valve alone to guard against shocks; for high speed hydraulic elevators, by which is meant elevators that travel 600 feet per minute or more, an **additional** valve called a **pilot valve**, or auxiliary valve as it is sometimes called, is used.

Horizontal Hydraulic Piston Elevators.—These elevators are usually made (1) Compression type, or (2) Tension type, but as the latter type is now almost exclusively used, it alone will be considered.

In Fig. 255 is shown a horizontal hydraulic passenger elevator with the different parts.

Parts.—

1. Cylinder.
2. Closed or back cylinder head.
3. Open or front cylinder head.
4. Buffer.
5. Crosshead.
6. Machine sheaves.
7. Machine sheaves shafts.
8. Double or crosshead cable guards.
9. Small or crosshead buffer ring.
- 9½. Large or piston buffer ring (covered).
10. Carwheel.
11. Carwheel shaft.
12. Piston rod.
13. Cable roller.
14. Cable roller shaft and oil cup.



Horizontal Hydraulic Passenger Machine.
Fig. 255.

15. Cylinder drawbars and clevises.
16. Cylinder head arms.
17. Triple or blackhead cable guard.
18. Guard rods and pipes.
19. Guide rail stand.
20. Guide rails.
21. Buffer bolts.
22. Cylinder arm brace.
23. Automatic stop tappet.
24. Automatic stop cam rollers.
25. Automatic stop cam.
26. Automatic stop cam balance lever.
27. Automatic stop cam balance lever weight.
28. Automatic stop front head bracket or cam shaft.
29. Automatic stop tappet rod.
30. Automatic stop tappet rod clamp button.
31. Automatic stop tappet roller.
32. Automatic stop crosshead bracket.
33. Automatic stop tappet rod guide.
34. Automatic stop tappet rod guide pipe.
35. Automatic stop floor plate.
36. Automatic stop connecting rod.
37. Automatic stop connecting rod turnbuckle.
38. Automatic stop connecting rod fork end.
39. Automatic stop valve stem rocker or lever.
40. Automatic stop valve stem rocker shaft.
41. Auxiliary change valve.
42. Automatic stop valve.
43. Rocker arm with drawbar and clevises.

Construction.—Both the fixed and the traveling sheaves are located at the front of the cylinder, these sheaves being mounted in the crosshead at an angle to the horizontal plane. In order to occupy as little floor space as possible the cylinders are made very short,

which necessitates a high ratio of the transmitting devices. This ratio is generally chosen as 10:1, by which is meant that for every 1 foot that the piston moves, the car will travel a space of 10 feet. After the automatics go into operation the car should run five or six feet to avoid the jar of a too sudden stop.

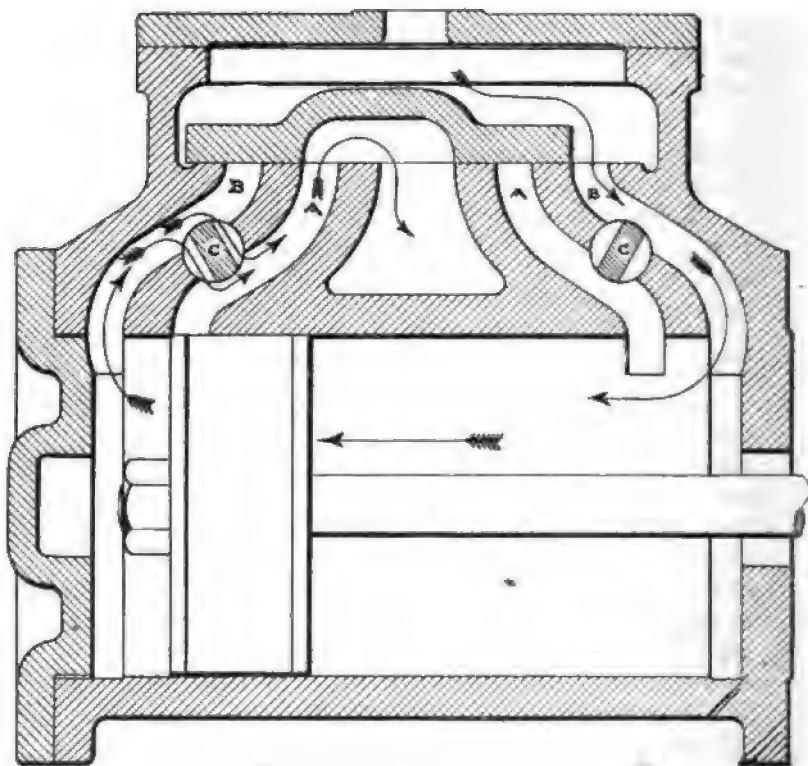
The general construction of the horizontal type is similar to that of the vertical type, the chief difference being in the safety limit stops.

Safety Limit Stops.—The construction and operation of this stop is as follows: The valve has three pistons, of which the first two serve to close the circular openings leading from the inlet to the outlet.

The valve stem is connected by a lever and rod to a cam pivoted to the frame of the machine. This cam is ordinarily held between two rods by means of a weight attached to it. The rollers are placed on a movable frame guided horizontally as shown and called the tappet. On the guide rod of this tappet are fastened the limit stop buttons to the right and left of a projection or arm on the cross of the traveling sheave. In either of the extreme positions of the crosshead, the arm comes in contact with one or the other of the buttons, pushing the tappet and thus operating the stop valve, and shutting off the communication between the main valve and the cylinder.

Dash Relief Valve for Pumps.—As the functions of this valve are not generally understood, in Fig. 256 is shown a sectional view of same, the general construction of the valve being as follows:

Construction.—"A" is the exhaust port, "B" the admission port, and "C" a valve connecting them, fitted with a spindle, working through a stuffing-box, and controlled from the outside of the cylinder by a hand-wheel,



Dash Relief Valve for Pumps.

Fig. 256.

it will be seen that when the piston travelling in the direction indicated covers the opening of the exhaust port as shown, the volume of steam remaining in the cylinder can no longer escape if the relief valve is closed, but immediately forms a **cushion**, whereas if the relief valve is open as shown in sketch, the steam flows by the admission port through the relief valve to the exhaust port, and the piston continues its stroke.

In this way the amount of steam cushioned can be regulated by adjusting the relief valve, and perfect control over the length of the stroke can be maintained.

HOW TO PACK HYDRAULIC VERTICAL CYLINDER ELEVATORS, AS GIVEN BY THE MANUFACTURERS.

Packing Vertical Cylinder Piston from Top.—Run the car to the bottom, and close the gate valve in the supply pipe. Open the air cock at the head of the cylinder, and also keep open the valve in the drain pipe from the side of the cylinder long enough to drain the water in the cylinder down to the level of the top of the piston. Now remove the top head of the cylinder, slipping it up, the piston rods out of the way, and fasten there. If the piston is not near enough to the top of the cylinder to be accessible, attach a rope or small tackle to the main cables (not the counterbalance cables), a few feet above the car, and draw them down sufficiently to bring the piston within reach. Remove the bolts in the piston follower by means of the socket wrench furnished for that purpose. Mark the exact position of the piston follower before removing it, so that there will be no difficulty in replacing it. On removing the piston follower you will find a leather cup turned upwards, with coils of $\frac{5}{8}$ inch square duck packing on the outside. This you

will remove and clean out the dirt, also clean out the holes in the piston, through which the water acts upon the cups. If the leather cup is in good condition, replace it, and on the outside place three new coils of $\frac{5}{8}$ inch square duck packing, being careful that they break joints, and also that the thickness of the three coils up and down does not fill the space by $\frac{1}{4}$ inch, as in such case the water might swell the packing sufficiently to cramp it in this space, thus destroying its power to expand. If too tight, strip off a few thicknesses of canvas. Replace the piston follower, and let the piston down to its right position. Replace the cylinder head, and gradually open the gate valve in the supply pipe, first being sure that the operating valve is on the center. As soon as the air has escaped, close the air cock and the elevator is ready to run.

Packing the Vertical Cylinder Valves.—To pack the valve run the car to the bottom and close the gate valve in the supply pipe. Then throw the operating valve for the car to go up, open the air cock at the head of the cylinder, and the valve in the drain pipe at the bottom, and the water will drain out of the cylinder. When the cylinder is empty, reverse the valve for the car to run down, so as to let the water out of the circulating pipe. In cases of tank pressure, where the level of the water in the lower tank is above the bottom of the cylinder, the gate valve in the discharge pipe will have to be closed as soon as the water in the cylinder is on a level with that in the tank, allowing the rest to pass through the drain pipe to the sewer. As soon as the water has all drained off, take off the valve cap and remove the pinion shaft and sheave, marking the position of the sheave and the relation which the teeth on the pinion bear to the teeth on the rack before removing. You can now take out the valve plunger, and put the new packings on in

the same position as you find the old ones. Replace all the parts as first found.

Before refilling the cylinder, close the valves in the drain pipes, but leave the air cock at the head of the cylinder open, and be careful that the operating valve is in position for the car to go down. Gradually open the gate valve in the supply pipe. When the cylinder has filled with water and the air has escaped, close the air cock and open the gate valve in the discharge pipe.

Packing Horizontal Hydraulic Elevators.—Run the car to within one foot of the extreme top and secure it to the overhead beams with chain or rope. Close the gate valves in the supply and discharge pipes and open the air cock in the small pipe leading to the valve. Then draw the water from the cylinder by opening the stop cock in the drain pipe leading from below the supply elbow. Now remove the buffer across the front end of the cylinder and slide it along the piston rod out of the way. Remove the follower by taking off the nuts. With a hooked piece of wire take out the old packing. Raise the piston head up till it is in the center of the cylinder. If the cylinder is found to be in good condition, cut off four rings of one inch square lubricated fibrous packing nine inches longer than the circumference of the cylinder. Place the two ends of a ring together and form tucks with the balance. Force these tucks in, one at a time, with a hard wood stick until all is level against the head. Proceed in same manner with remainder of packing. So arrange packing that the joints in the different rings do not come together. If the cylinder is badly worn, use square pure rubber packing for the first and last ring and make the rubber rings but one inch longer than the circumference of the cylinder. This rubber insures a backing for the fibrous packing. After putting

packing in position, replace the follower and screw the nuts on with the fingers, until the follower is close against the packing. On two of the studs opposite each other will be found jam nuts. Set these out against the follower and tighten with a wrench. Replace the buffer and draw the large nuts up tight. Close the drain cocks and shift the operating valve for going up. Open the gate valve in the supply pipe and fill the cylinder. When cylinder is filled close the air cock. As the car in the first place was not at the extreme top, the pressure in the cylinder will run the piston head up against the machine buffer and the car will ascend to the extreme top. The fastenings may then be removed. Throw the operating valve on the center and open the discharge. The elevator is then in readiness to descend. Do not make any trips until the cylinder is thoroughly greased. Continue greasing twice a week.

In the course of time leaks will occur in the cylinder. Loosen the jamb nuts back of the follower and set up the nuts on the studs equally until the leak is stopped. Then retighten the jamb nuts.

Otis Gravity Wedge Safety.—I. Under the car is a heavy **hardwood safety plank**, on each end of which is an iron adjustable jaw, enclosing the guide on the guide post. In this jaw is an iron wedge, withheld from contact with the guide in regular duty. Under the wedge is a rocker-arm, or equalizing bar, with one of the lifting cables, attached **independently** at each extremity. The four lifting cables, after being thus attached, pass over a wrought iron girdle at the top of the car. Each cable carries an equal strain, and the breaking of any one cable puts the load on the other cables, which throws the rocker out of equilibrium, and forces the wedges on **both** sides instantly and immovably between the iron jaws of

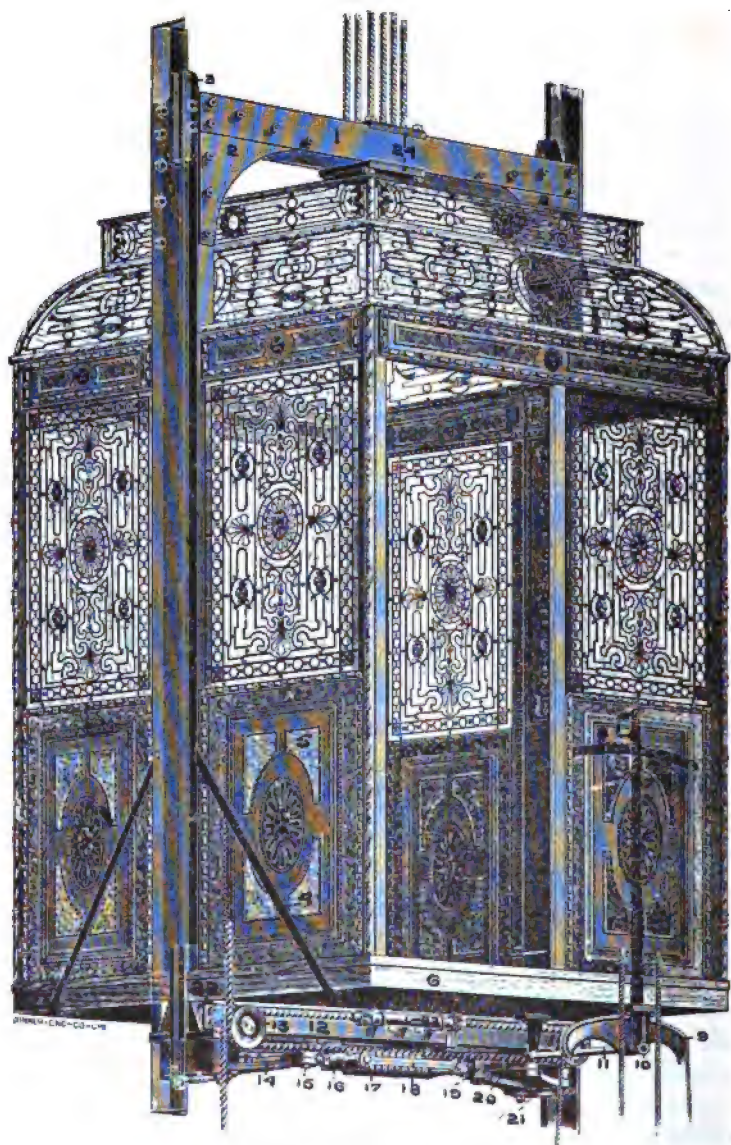
the safety plank and the side of the guides, **stopping the car.** It may be raised to any position by the unbroken cables, though it can not be lowered until a new cable is put on.

2. Any cable will always stretch before it breaks, which will throw the equalizing safety bar out of equilibrium and force the wedges on both sides into position. **No other safety device will give warning in advance.**

In Fig. 257 is shown an ordinary elevator cage or car, with its principal parts:

Parts.—

1. Cage beam.
2. Gusset plates.
3. Upper guide shoe.
4. Platform brace.
5. Car.
6. Cage platform.
7. Operating lever.
8. Operating lever quadrant.
9. Half moon.
10. Drop hanger.
11. Operating shaft.
12. Channel for safety plank.
13. Governor rope sheave on safety plank.
14. Friction jaws.
15. Pins for friction jaws.
16. Spring head (plain).
17. Safety spring.
18. Spring head connecting bars.
19. Coupling rod jaws.
20. Coupling links.
21. Friction jaw supporting link.
22. Bottom guide shoe.
23. Governor rope trigger, complete.
24. Upper and lower beam plates.



Elevator Car and Parts.

Fig. 257.

CARE OF HALE ELEVATORS, AS GIVEN BY THE MANUFACTURERS.

Keep the guide springs on the girdle above, and the safety-plank below the car adjusted so that the car will not wobble, but not tight enough to bind against guides.

When cables are drawing alike, the equalizing bars on a passenger elevator should be horizontal, and the set screws free from contact with the finger shaft, but adjusted so that one of them will come in contact with the finger shaft when the equalizing bar is tipped a certain amount either way.

If the safety wedges should be thrown in, or rattle, when descending, the cause would be from the stretching or breaking of one of the cables, the action of the governor, or from weakness of either the spring on the finger shaft, safety-wedge or gummy guides.

In the first case, if occasioned by the cable stretching, the cable should be examined thoroughly, and if it shows weakness, a new one put on, otherwise it can be shortened up, as stated above.

In the second case, the car had probably attained excessive speed, and the governor simply performed its proper function.

In the third case, new springs should be put on, and the guides kept clean, for it often happens that the guides are so dirty that the springs cannot well prevent the wedges catching.

All the safeties should be kept clean and in good order, so that they will quickly respond when called upon to perform their duty.

To loosen the wedges when thrown in, throw the valve for the car to ascend.

If the wedges are thrown in above the top landing,

remove the button on the hand cable, and run the car up until the piston strikes the bottom of the cylinder. If this is not sufficient to loosen the wedges, the car will have to be raised by a tackle.

Keep all nuts properly tightened.

If traveling or auxiliary sheave bushing is worn so that sheave binds, or the bushing is nearly worn through, turn it half round, and thus obtain a new bearing. If it has been once turned, put in a new bushing.

See that the piston rods draw alike. If they do not, it can be discerned by trying to turn the rods with the hand, or by a groaning noise in the cylinder. However, this groaning may also be caused by the packing being worn out, in which case the car would not stand stationary.

See that all supports remain secure, and in good condition.

If car settles, the most probable cause is that the valve or piston needs repacking. If packing is all right, then the air valve in the piston does not properly seat.

If the car springs up and down when stopping, there is air in the cylinder. When there is not much air, it can often be let out by opening the air cock and running a few trips, but when there is considerable air, run the car to near the bottom, placing a block underneath for it to rest upon, then place the valve for the car to descend. While in this position open the air cock and allow the air to escape. This may have to be repeated several times before the air is all removed.

Keep the cylinder and connections protected from frost. Where exposed, the easiest way to protect the cylinder is by an air-tight box, open at the bottom, at which point keep a gas jet burning during cold weather.

Where there is steam in the building, run a coil near the cylinder.

Keep stop buttons on hand cable properly adjusted, so that the car will stop at a few inches beyond either landing, before the piston strikes the head of the cylinder.

Regulate the speed desired for the car by adjusting the back stop buttons, so that the valve can only be opened either way sufficiently to give this speed.

Occasionally try the governor to see that it works properly.

Keep the machinery clean and in good order.

Cables and How to Care for Them.—Wire and hemp ropes of same strength are equally pliable. Experience has demonstrated that the wear of wire cables increases with the speed. Hoisting ropes are manufactured with hemp centers to make them more pliable. Durability is thereby increased where short bending occurs. All twisting and kinking of wire rope should be avoided. Wire rope should be run off by rolling a coil over the ground like a wheel. In no case should galvanized rope be used for hoisting purposes. The coating of zinc wears off very quickly and corrosion proceeds with great rapidity. Hoisting cables should not be spliced under any circumstances. All fastenings at the ends of rope should be made very carefully, using only the best babbitt. All clevises and clips should fit the rope perfectly. Metal fastenings, where babbitt is used, should be warmed before pouring, to prevent chilling.

Examine wire ropes frequently for broken wires. Wire hoisting ropes should be condemned when the wires (not strands) commence cracking.

Keep the tension on all cables alike. Adjust with draw-bars and turnbuckles provided.

Lubrication of Worm Gearing.—Oils with a body, such as cylinder and castor oils, are best suited to the purpose. A composition of two parts castor to one part cylinder oil of very best quality, makes a desirable lubricant, for the following reasons: Cylinder oil being heavy with ample body, on becoming warm runs freely to the point of contact between the worm and gear and lubricates readily. On the other hand castor oil when cool or only slightly warm retains its body and makes an excellent lubricant. Upon becoming heated castor oil thickens, thus rendering it objectionable. By the combination efficient lubrication is obtained at all temperatures.

Lubrication of Cables.—A good compound for preservation and lubrication of cables is composed of the following: Cylinder oil, graphite, tallow and vegetable tar, heated and thoroughly mixed. Apply with a piece of sheepskin with wool inside.

To prevent wire rope from rusting apply raw linseed oil.

Lubrication of Guides.—Steel guides should be greased with good cylinder oil. Grease wood strips with No. 3 Albany grease or lard oil. Clean guides twice a month to prevent gumming.

Lubrication of Overhead Sheave Boxes.—In summer use a heavy grease. In winter add cylinder oil as required.

Leather Cup Packings for Valves.—Leather for cups should be of the best quality, of an even thickness, free from blemish, and treated with a water-proof dressing. The cups should be of sufficient stiffness to be self-sustaining when passing over perforated valve lining. When ordering cups, the pressure of water carried should be specified, as the stiff cups intended for high

pressure would not set out against the valve lining when low pressure is used.

Water.—Water for use in hydraulic elevators should be perfectly clear and free from sediment. A strainer should be placed on the supply pipe and water changed every three months, and the system washed and flushed.

Closing Down Elevators.—If an elevator is to be shut down for an indefinite period, run the car to the bottom, and drain off the water from all parts of the machine, otherwise a freeze is likely to burst some part of the machinery. If the machine is of horizontal type, grease the cylinder with a heavy grease; if vertical, the rods should be greased. Oil cables with raw linseed oil.

Lubrication for Hydraulic Elevators.—The most effectual method of lubricating the internal parts of hydraulic elevator plants where pump and tanks are used, is to carry the exhaust steam drips from the foot of the pump exhaust pipe to the discharge tank, thus saving the distilled water and cylinder oil. This system is invaluable when water holding in solution minerals is used, as these minerals greatly increase corrosion.

Horizontal machines operated by city pressure are best lubricated with a heavy grease applied either mechanically or by means of a piece of waste on the end of a pole. The former method serves as a constant lubricator, while in the latter case greasing is often neglected, and in consequence packing lasts but a short time.

Useful Information.—To find leaks in elevator pressure tanks in which air is confined, paint around the rivet heads with a solution of soap and the leak will be found wherever a bubble or suds appear.

To ascertain the number of gallons in cylinders and round tanks, multiply the square of the diameter in

inches by the height in inches and the product by .0034 = gallons.

Weight of round iron: Multiply the diameter by 4, square the product and divide by 6 = the weight in pounds per foot.

To find the weight of a casting from the weight of a pine pattern, multiply 1 pound of pattern by 16.7 for cast iron and by 19 for brass. Ordinary gray iron castings = about 4 square inches to the pound.

Horse Power of Belting.—To ascertain transmitting power, multiply diameter of driving pulley in inches by its number of revolutions per minute and this product by width of belt in inches; divide this product by 3,300 for single leather, four-ply rubber or four-ply cotton belting—or by 2,100 for double leather, six-ply rubber or six-ply cotton belting, and the quotient will be the number of horse power that can be safely transmitted.

Belts and How to Care for Them.—The work required of an elevator belt is the most severe and we might say extraordinary character, running as it does over a large to a small pulley and beneath an idler, so situated as to give the small pulley as much belt surface as possible. The belt runs forward and backward as the cage ascends and descends, thereby causing a certain amount of slip. It is imperative that a belt performing such service should be of the very best quality. The following are the specifications:

The stock should be strictly pure oak tanned, cut in such a manner that the center of the hide will form the center of the belt. Each piece should have all stretch thoroughly removed. The belt should be short lap, none of the pieces to exceed 4 feet 2 inches in length, including the laps. Lock lap should be made which makes a perfect splice. Under no circumstances should

a straight lap be used. The cement should be of the very best quality and pliable to such an extent that it will allow for the short turn taken by the belt passing under the idler and around the small pulley. As a precaution against laps coming apart from accident or other cause, belts should be riveted, as the rivets will hold lap together until defect may be seen and remedied.

Owing to the high speed, laced belts should never be used, as the laces are sure to be cut by running over the small pulleys.

Castor oil makes a very reliable dressing for belts. It renders them pliable, thus improving the adhesive qualities.

Electric Elevators.—This type of elevators are made either (1) indirect-connected, or (2) direct-connected.

Indirect-Connected.—In this arrangement, the electric motor is simply used for driving the **line-shafting** of an ordinary belt elevator.

Direct-Connected.—In this arrangement is eliminated the counter-shaft and the tight and loose pulley, and the substitution therefor of a belt connecting the motor **directly** with the machine.

In the modern elevator the belt is also eliminated, and the motor is coupled directly to the **shaft** of the elevator machine. Such a machine is shown in Fig. 258.

Motors.—As the motor must start under load, it must therefore get up speed rapidly, though gradually.

When it is relied upon the motor **alone** to do this, it is then generally constructed of the compound wound type, the series coil serving to give the torque at starting, and the shunt coil **steading** the field. When the motor is up to speed, the series coils are generally cut out, leaving the motor to be run as a simple shunt wound motor.

Where the operation of the motor is **not** relied upon alone, then controlling devices are used, which are hereinafter described.

Transmitting Devices.—Such devices between the motor and car consist of the ordinary worm gearing, drum, and rope.

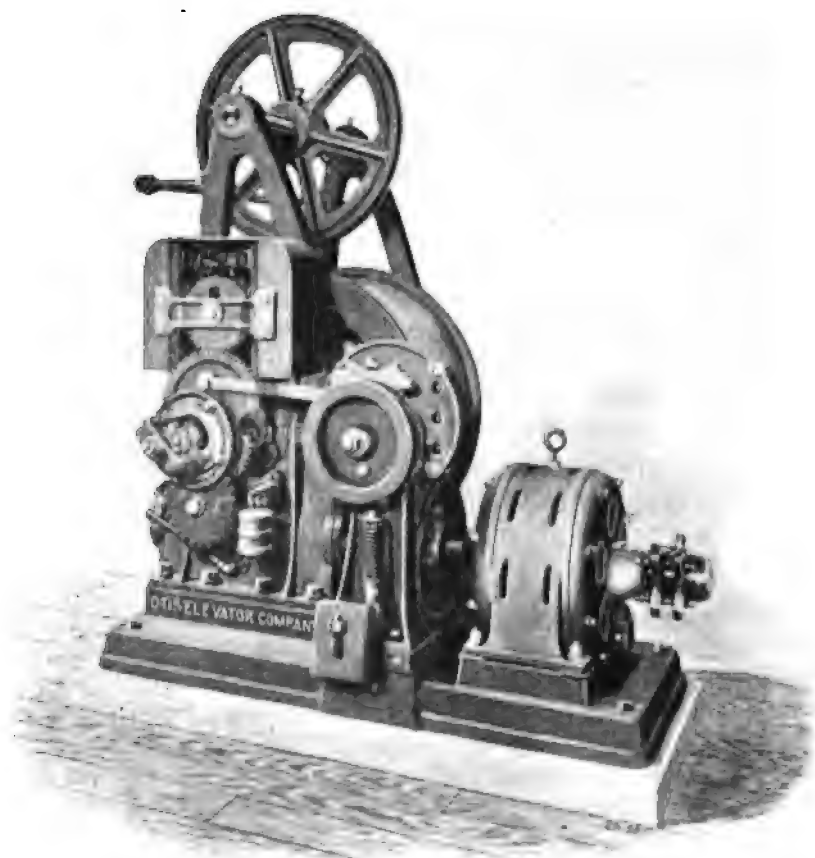
Controlling Devices.—The power control consists of **breaking** the current, and the **reversing** of the motor. While a simple snap switch is all that is necessary to break the current, to **reverse** the travel of the car, i. e., the rotation of the motor, a reversing switch or pole changer is needed.

In practical operation of elevators, the complete apparatus necessary to control the electric motor is called a **controller**.

Counter-Balancing.—Direct connected electric elevators of the drum type are always over-balanced.

Electric Elevator Engines.—In Fig. 258 is shown the Otis Electric Elevator Engine with alternating current motor, for either passenger or freight service. These engines are designed for operation on two-phase or three-phase circuits of any commercial voltage and frequency, and can be provided with either electrical or mechanical control. The engine shown is arranged for mechanical control.

Systems of Control.—There are two systems of control for electric elevators—the **electrical** and the **mechanical**. In the former, the elevator is controlled by a small switch within the car, operating pilot circuits which open and close the main line and reversing switches. On starting, there is considerable resistance within the armature circuit, and as the motor accelerates this resistance is automatically cut out step by step by electrically operated switches. By this means, the current is abso-



The Otis Electric Elevator Machine.
Fig. 258.

lutely prevented from increasing above the amount for which the motor is designed and a gentle start, proportionate to load, is secured.

The **mechanical** system of control differs from that just described in that the line switch is opened, closed, and reversed through the medium of a lever or a hand-wheel within the car, by purely mechanical means. Closing the switch admits starting current only to the motor and thereafter the control proceeds in the manner already described in the respect that the starting resistance is cut out from the armature circuit by automatic switches step by step as the motor accelerates, the same protection of the motor against heavy currents being thereby afforded.

DIRECTIONS FOR THE CARE AND OPERATION OF THE CRANE OR OTIS ELECTRIC ELE- VATORS, AS GIVEN BY THE MANUFAC- TURERS.

Warning.—Whenever the attendant wishes to handle the machine to clean, adjust, repair or oil it, he should see that the current is shut off at the switch and thus prevent all possibility of accident.

Cleaning.—Keep the entire machine clean.

Clean the commutator and other contacts and brushes carefully with a cloth and keep them free from grease and dirt.

If the face of the rheostat on which the rheostat arm brushes work becomes burnt, clean with a piece of fine sandpaper (No. 0), or if necessary use a fine file.

Keep all contacts smooth.

Try the rheostat arm when cleaning to be sure that it moves freely off contacts.

Oiling.—Oil the drum shaft bearings with good heavy oil.

Oil the worm and gear by filling the chamber around them with a mixture of two parts of good castor oil and one part good cylinder oil. Keep this chamber filled to the top of worm or mark on gauge glass, adding a little each day as it is used. The end thrust bearings of the machine are automatically oiled from this chamber. This should be drawn off every two or three months and replaced by fresh oil.

Oil the motor bearings with dynamo oil. These are automatically oiled, but should occasionally be supplied with fresh oil. Lubricate the commutator, rheostat face, drum switch and contacts **very sparingly** with a cloth moistened with oil. Care should be taken not to apply too much oil to these parts.

Keep the oil dash pot, if any, sufficiently filled with oil to allow the rheostat arm to move quickly on to the first contact and to retard its movement beyond this contact. The best oil for this purpose is fish oil or some thin oil that is not readily affected by changes in temperature.

If an air dash pot is used keep it slightly oiled so as to keep the packing soft.

Keep all parts of the elevator, including sheaves, guides, cables, etc., clean and well oiled.

Operating.—Before switching the current on to the machine, be sure that the operating lever is in its central position.

To ascend, draw the lever the full throw to the **up**.

To descend, draw the lever the full throw to the **down**.

To run at slow speed, bring the lever toward the center according to the speed desired.

To stop, bring lever to slow speed when within four feet of landing, and to its central position when close to it. In this way the operator can make accurate stops.

When starting (machines on which the solenoid is used) if the current is admitted to the motor too rapidly, thereby starting the car with a jerk or momentarily dimming the lights on the circuit, check the speed with which the resistance is cut out of the armature circuit by slightly easing off the weight which acts in opposition to the core of the small solenoid. This solenoid controls a valve in the dash pot and thereby regulates its speed in proportion to the current passing.

If a governor starter is used and the current is admitted too rapidly tighten the governor spring on the armature shaft, or close the vent in air dash pot.

If the car refuses to ascend with a heavy load, immediately throw the lever to the center and reduce the load, as in all probability it is greater than the capacity of the elevator.

If it refuses to ascend with a light load, throw the lever to the center and have the fusible strip examined.

If in descending the car should stop, throw the lever to the center, and examine safeties, fusible strip and machine, and before starting be sure that the cables have not jumped from their right grooves.

If the car refuses to move in either direction throw the lever on the center and have the fusible strips examined. Never leave the car without throwing the lever to the center.

If the car should be stalled between floors, it can be either raised or lowered by raising the brake and running it by turning the brake wheel by hand. Such a stoppage might be caused by the current being shut off at the station, undue friction in the machine, too heavy a

load, fuses burnt out, or a bad contact of the switches, binding posts or electrical connections.

If the car by any derangement of cables or switch cannot be stopped, let it make its full trip, as the automatic stop will take care of it at either end of the travel.

The bearings should be examined occasionally to insure no heating and proper lubrication.

The attendant should inspect the machine often.

All brushes and switches should be sufficiently tight to give a good contact, but no tighter.

None of the brushes should spark when in their normal position.

When the brushes become burnt dress with sandpaper or a file, or if necessary replace with new ones.

If brushes spark, dress with sandpaper or file to a good bearing, and if necessary set up springs, but do not make the tension such as to interfere with their ready movement.

Adjust commutator brushes gradually for least sparking. These should be close to the central position.

Contacts and brushes should be kept clean and smooth, and lubricated sparingly.

While replacing a fusible strip, be sure that main switch is open, and be careful not to touch the other wire with your tool or otherwise, as such contact would be dangerous.

Never put in a larger fuse than the one burnt.

Inspect the worm and worm wheel occasionally through hand-hole in casing to see that they are well lubricated and that no grit gets into the oil. They should show no wear.

The stuffing-box on the worm shaft should be only tight enough to keep the oil from leaking out of the worm chamber.

Be sure that all parts are properly lubricated, and that none of the bearings heat.

To make sure that the car and machinery run freely, lift brake lever and then rotate worm shaft by pulling on the brake wheel. The empty car should ascend without any exertion.

Keep operating cables properly adjusted.

Open main switch when the elevator is not in service.

The Marine Electric Elevator.—The construction of this elevator, as shown in Fig. 259, possesses many excellent points; therefore, the specifications for this machine are given below, not only to show the characteristic features, but as a most instructive way to present to the student the requirements in the construction of a modern electric elevator.

Construction.—Bed Plate.—One solid iron casting to keep all bearings in perfect alignment.

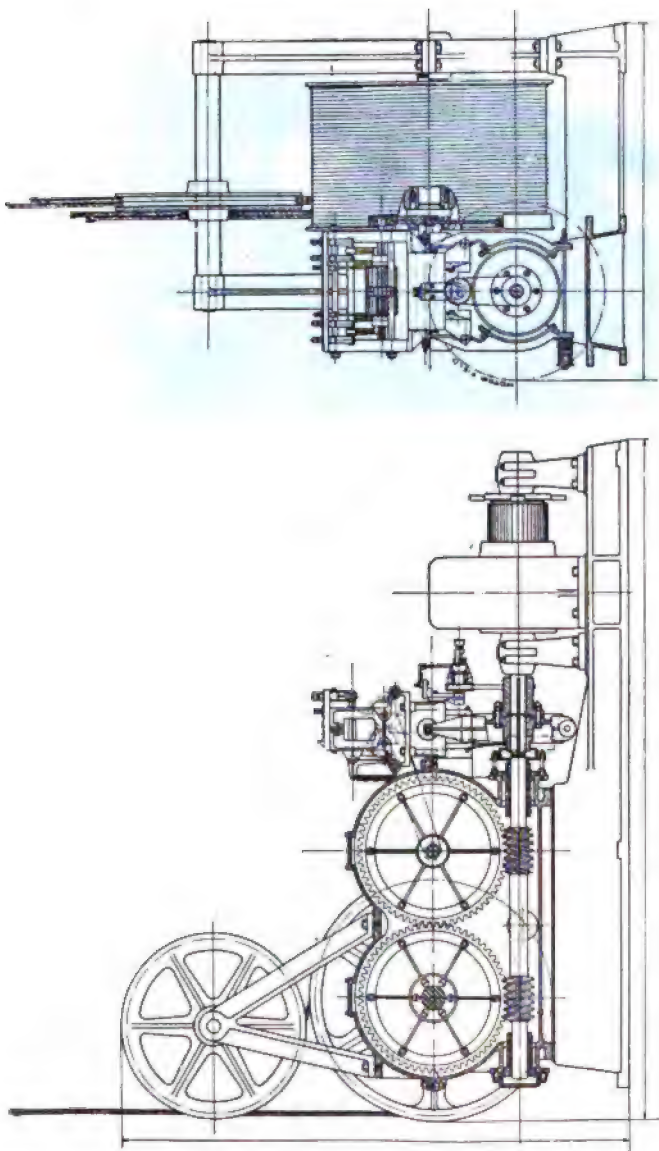
Motor.—The motor is of the slow speed multipolar type, compound wound, having a strong series field to promote easy starting, and will stand temporary excessive overload without flashing at the brushes or injurious heating.

The armature is wound with formed coils and perfectly ventilated, balanced both electrically and mechanically and runs in self-aligning and self-oiling bearings.

The brushes are carbon and independently adjustable.

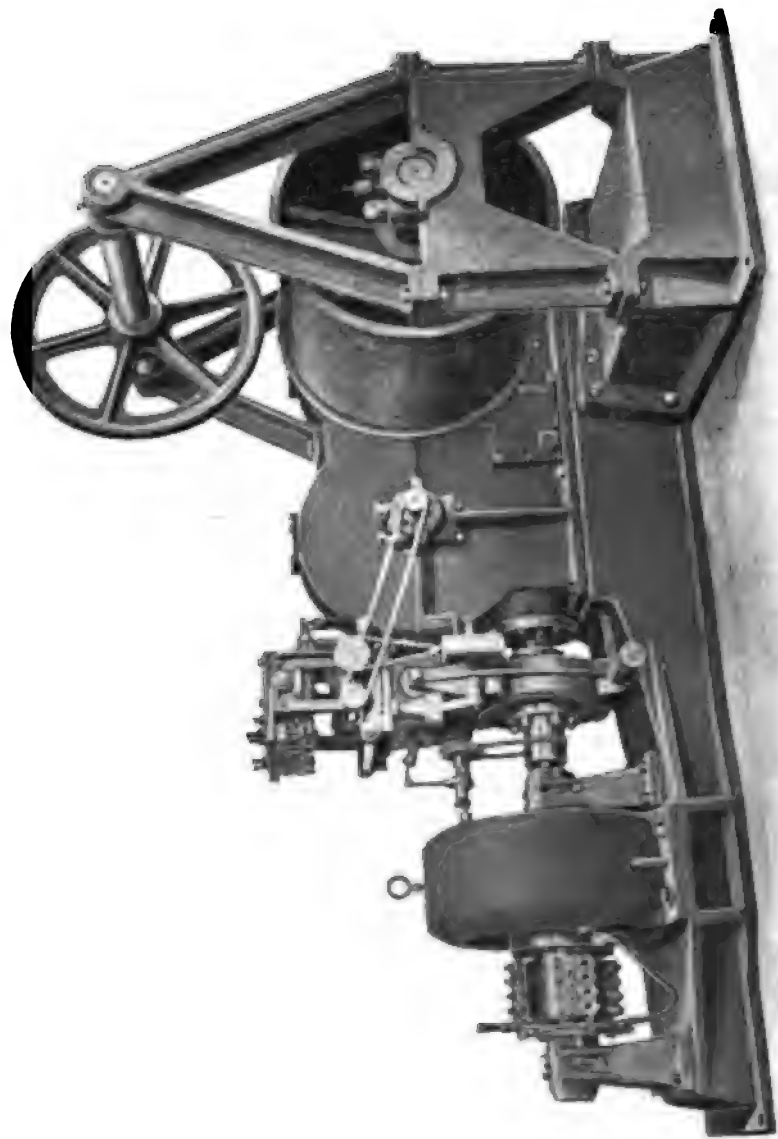
Gears.—The gears, of the best bronze, are cut on a spiral gear cutter, the teeth are the helical form that mesh perfectly and give the smoothest possible motion.

Worms.—The worms are a part of the high carbon hammered steel worm shaft, and are hobbled into the spiral gears.



Sectional View of the Marine Electric Elevator.

Fig. 259.



The Marine Electric Elevator Machine, Showing Motor.
Fig. 259-(2).

Drum.—The drum is secured and driven by six (6) turned coupling bolts fitted into reamed holes in a flange forged on to the drum shaft. The gear spider is secured in the same way to the same shaft.

Brake.—The brake magnet, to which the brake levers are pivoted, is bolted to the gear case. The shoes are made of cast iron lined with cork formed to fit the pulley. The pressure is applied by a spring and released by energizing the magnet.

Limit.—The limit is mounted on the brake magnet and driven by a nickel steel sprocket chain, of 2,500 pounds breaking strength, from the gear shaft.

Slack Cable Device.—The slack cable device is a balanced bar under the drum, bringing the controller to stop upon the slacking of the ropes.

Governor.—A centrifugal governor, driven by the worm shaft, applies the brake whenever the normal speed is exceeded.

Lubrication.—All bearings are self-oiling. The worms run entirely submerged, and the oil, paddled up by the gears, flows through the gear shaft bearing and back into the gear case.

THE MARINE MAGNET CONTROLLER.

Contruction.—This type of controller has been designed for use in connection with high speed electric drum machines, where rapid acceleration and general hard service is demanded of the apparatus. Every detail of the design and manufacture of this new type of controller has been most carefully worked out, and only such parts have been utilized in its assembly as long service has demonstrated them to be best suited for the service demanded.

Essential Features.—The essential features of this

controller are the reversing switches shown on the lower panel, and the six accelerating magnets on the upper panel. The Series Field Magnet between the reversing switches operates automatically to cut out the series coil of the motor, after the machine has started. The small relay controls the circuit to the accelerating magnets and the machine brake coil.

Reversing Switches.—The reversing switches are operated by the cores of the magnets, against gravity, to close the circuit to the motor. Rapid and positive action is assured in this form of electro-mechanical switch with failure to open unknown. The contacts are of copper and carbon, of large capacity, independently adjustable and having long life.

Accelerating Magnets.—The six accelerating magnets control the starting resistance in the main motor circuit, and are so connected that they must operate in succession to short circuit the sections of the resistance which they control.

The accelerating magnets are made up of the standard parts used on the reversing switches and operate against gravity, to cut out the starting resistance.

Starting Resistance.—The starting resistance consists of a bank standard cast iron grids, mounted on a slate base at the rear of the controller. This type of "current diverter" is practically indestructible, and is the standard for all heavy electrical duty of this character.

Car Switch.—The car switch is of the "automatic stop lever" type, especially designed for use in connection with the magnet controller. The lever is automatically locked on the "stop" position and cannot be moved unless the latch under the handle is first raised. The contacts are easily renewed if required.

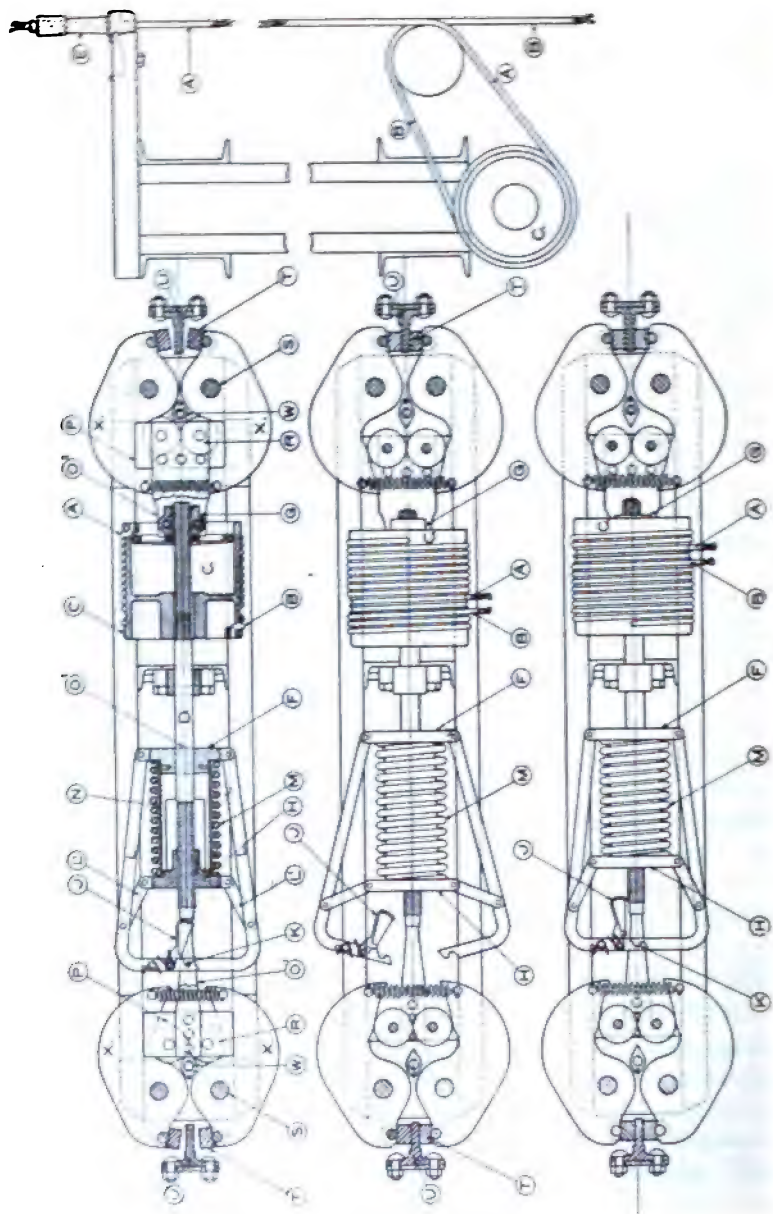
By means of this switch, variable speeds and instant reversal of car movement are easily obtained.

Controlling Cable.—The junction boxes shown with the car switch are used, one at the center of the hoistway and one under the car, to provide a suitable means for supporting and connecting up the electric controlling cable. This cable has a steel supporting core for relieving the “conducting” wires from strain, which are separately insulated from the core and each other. The whole cable is covered with “fire-proof” braid.

The Pratt Elevator Safety.—This safety is used on the Marine make of elevators; and is a most successful device.

Construction.—Fig. 260 shows the safety as seen when looking up at it from below the car, and in three different positions, viz.: “No pressure on rails,” or when the jaws are clear of the rails by one-fourth inch and the car is ready to run; “spring pressure” on rails, or the first grip of the jaws by the pressure of the spring when unlatched the instant that the speed governor grips the rope; “maximum pressure” on rails or when the load and speed are such that it requires the full spring pressure to stop the car.

Device to Grip the Rails.—The principle of the gripping device on the car is the application of a spring to set the jaws on the rails instantly the speed is exceeded, and then to use the power of the moving car (which for this purpose is, of course, unlimited) to gradually compress this spring and in so doing steadily increase the pressure of the jaws on the rails through such a distance of car travel that any load at any speed will be brought to a safe and easy stop, and without bringing any undue strain on any part of the apparatus. The



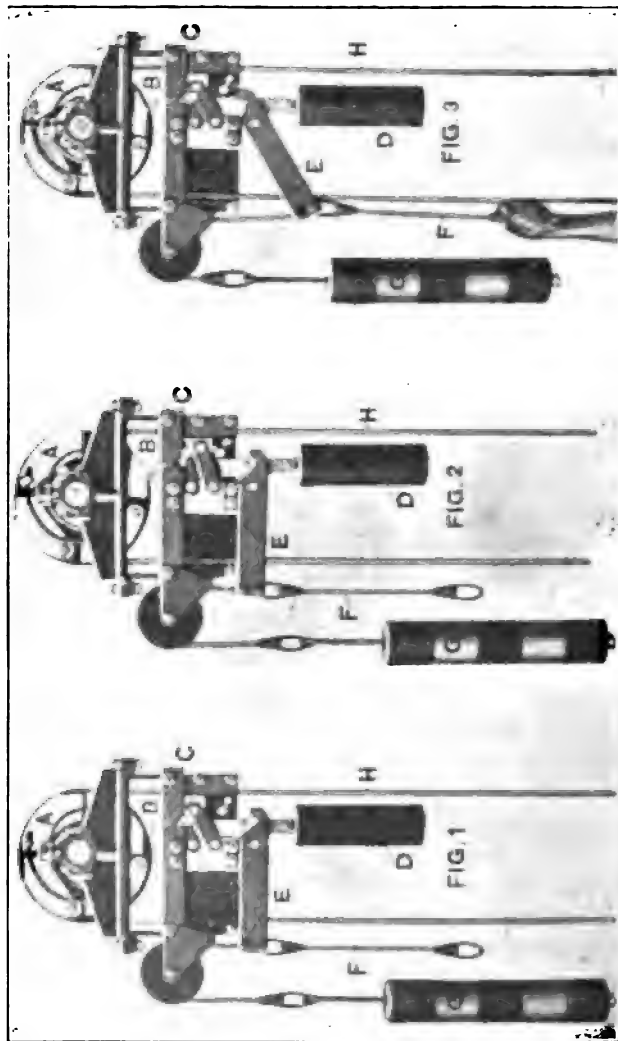
The Pratt Car Safety Device.
Fig. 260.

particular mechanism by which this is accomplished is shown in Fig. 260.

Operation of Governor.—Fig. 261 shows spring F closed, either by the travel of the car under maximum load and speed, or by pulling the governor rope by hand to relock the toggles before the screw C is revolved in the reverse direction by hand pull on the governor rope, in order to push back the wedges H and J and restore the safety to the position “no pressure on rails.”

Governor Rope.—This figure has a sketch showing the rope connections between the governor and the car, in which B is the rope passing over the governor sheave T, leading down through the driving grip Y on the car, under the idler sheave and around the drum A where this end of it is anchored at B, as shown in the sectional view. The other end of this same piece of rope is shown on the sectional view anchored at S on the drum A, passing over an idler sheave and down to the tension sheave U at the bottom of the hoistway. Here is one continuous rope, without the several splices or connections common to other systems and being wound around the drum A in both directions enables the safety to be released by the engineer outside of the car from any point in the hoistway. It will be seen from this sketch that the governor rope is driven by the car by grip Y until the adjusted speed is exceeded, when the governor grips the rope, stops it, driving grip Y releases, the car continues to travel, and the drum A to revolve until the car is stopped by the gradual pressure of the jaws on the rails.

The Pratt Car Safety Device.—The action of the safety device on the car (the success of which depends



The Marine Magnet Controller.
Fig. 261.

in the first place upon a reliable governor as above described) is as follows:

Construction.—Drum A is keyed on the right hand thread of shaft C. Shaft C has a right hand thread on the right hand end and a left hand thread on the left hand end. At the first advance of the left hand end of the screw through the nut E, it pushes the push bar P and trips the latch Q, unlocks the toggles RR and allows the spring F to extend. When the spring F extends, it carries nut E, screw C and wedges H to the left, and spring head G and wedges J to the right. Wedges H and J, being thus drawn together, separate each pair of rolls K, thus moving the two pairs of levers L about their pivots M and brings the jaws N against the steel guide rails O. This is the position marked "Spring pressure" in Fig. No. 260, and only brings the jaws on the rails with sufficient pressure to check and not to stop the car. Further travel of the car continues to revolve screw C, compressing spring F, and increasing the pressure of the jaws on the rails until the car is brought to an easy stop.

Governor Grip.—The grip on this governor is so accurately in line with and so near to the sheave that the rope cannot rub on and wear it. It is also a long **grooved jaw** that will not injure the rope.

The Marine Governor.—Fig. 261 shows the speed governor with side plate removed to show the rope grip. In this governor four freely pivoted weights, held by a spiral spring against centrifugal force, fly out, at whatever speed the tension of the spring is adjusted for, and a lug on the weight approaching the latch, strikes this latch and releases the latch pin and allows the weight to fall and bring the toggle grip against the rope. For safeties that are required to stop the car going either up

or down this gripping device is repeated on the other side of the governor, the lugs made to strike both ways, and the latches designed to suit the conditions.

Specifications.—The following are proper specifications for this governor: The elevator shall be provided with a safety device operated by centrifugal speed governor (located overhead), whereby upon excess of normal speed the centrifugal governor grips and positively stops the safety rope, and whereby the stopping of the safety rope brings the gripping jaws on the car in contact with the rails in not over two feet distance of car travel, and whereby the further travel of the car up to a distance of six feet steadily increases the pressure of the jaws on the rails until the car is brought to a safe and easy stop.

The Jones Controller.—These controllers were designed for use with hoisting machines where one fixed car speed is desired and are suitable for use with motors up to 25 horse power capacity.

Fixed Speeds.—They may also be used with motors having special shunt field windings, giving two fixed car speeds.

Special Features.—The essential features of this type of controller are the resistance regulator and the magnetic reversing switches.

Resistance Regulator.—The resistance regulator consists of the usual brush arm carrying four large independent contacts traveling over the copper contact plates to which the cast iron resistance grids are connected by an improved method.

Rheostat Operation.—The brush arm is operated by the core of the solenoid directly above it by means of the link connecting these parts, and is held in the full

speed position by the lock lever located at the left of the rheostat, under the small relay.

Automatic Locking.—At the same instant that the brush arm is locked in this full speed position, the current is automatically cut off from the solenoid coil operating the regulator, thereby preventing heating of the coil in operation.

Gravity Return.—In stopping, the plunger of the relay magnet falls on the lock lever and releases the brush arm, allowing it to return by gravity to the normal "stop" position.

Reversing Switches.—The reversing switches are of standard type, closing against gravity by the action of the core of the operating magnets. The contacts are **extra large** for the duty required and consist of independently adjustable carbon and copper pieces always presenting a flat surface to the contact plates attached to the magnet plungers.

Large Carrying Capacity.—This design insures the maximum carrying capacity and the minimum wear on the parts.

Cannot Start Too Suddenly.—The operating coils of the reversing switches are so connected that the **switches cannot be closed until the brush arm has returned to the normal starting position**, thereby introducing all of the starting resistance in the armature circuit and preventing too rapid starting of the elevator.

Impossible to Overload Motor.—A desirable feature of this controller is an adjustment which is provided to prevent, automatically, the starting of the motor when the car contains a load in excess of the usual maximum capacity. This device prevents overloading of the motor beyond its safe limit.

SPECIFICATIONS FOR THE W. A. MILLER DIRECT CONNECTED ELECTRIC ELEVATORS.

Electric Current Controllers and Safety Devices.—

The electric motors will be run in either direction to run the elevators up or down as desired by the electric reversing switch, which is operated by either the operating cable or lever from the platform or landings. By working the operating cable or lever the reversing switch is closed in the proper way to run the motor in the direction to send the elevator, either up or down, as desired. As soon as the electric reversing switch is closed the electric current controller will allow the electric current to enter the motor with a gradually increasing force so as to quickly and smoothly start the elevators. This current controller will start the elevator with a smooth motion, whether the operator starts the elevator quickly or slowly.

Slack Cable Stop.—There will be devices on the hoisting machine which will automatically stop the elevator by cutting out the current and applying the safety brake in case the hoisting cables should get slack or break, and thus prevent accident and the breaking and entangling of cables.

Machine Stops.—On the hoisting machine will be a device which will automatically stop the elevator by cutting out the current and applying the safety brake when the elevator reaches either top or bottom landing.

Safety Brake.—On the hoisting machine will be a safety brake which will gradually and smoothly stop the platform and elevator when the current has been cut out.

Operating Cable Stops.—On the operating cable will be a device which will automatically stop the elevator by cutting out the current and applying the safety brake when the platform reaches either the top or bottom landing, if the operator should neglect to stop the elevator.

SPECIFICATIONS FOR A MOLINE DIRECT-CONNECTED ELECTRIC FREIGHT ELEVATOR.

Motor.—The motor will be constructed especially for elevator service. It will be compound wound, and will be provided with "End On" carbon brushes, and will not spark. The motor is especially designed for obtaining a very quick start with a low consumption of current. The motor will be controlled by our automatic controller. The arrangement of the controller is such as to secure a gradual and easy start and stop of the elevator car, independent of the skill of the operator.

Hoisting Machine.—The hoisting machine will be made from our new and improved patterns, and will be securely fastened to overhead deck, furnished and placed by you.

This machine will be completed with solid forged steel screw on a steel shaft, and phosphor bronze worm wheel, and both worm and worm wheel will be accurately cut by special machinery to a standard gauge, and protected by an oil-tight chamber so that the worm will be surrounded with oil at all times.

The end thrust on worm shaft will be furnished with our improved anti-friction bearings, which make a large reduction in friction, and is guaranteed to run without heating. The bearings in this machine will be lined with the best quality copper hardened babbitt metal. It will have an automatic brake, limitation top and bottom stop, and slack cable stop.

The winding drum will be made extra heavy, of the best grade of cast iron, of suitable diameter, turned and grooved to receive $\frac{3}{4}$ -inch diameter cable.

All parts will be mounted on heavy cast iron bed plate, so that there can be no heating of bearings from parts getting out of line.

Cage.—Wainscoting of iron on two sides, 5 feet high. The cage, or platform, will be made of channel steel frame and of side post pattern. It will be 12 feet postway, and 14 feet from front to back. It will be arranged to travel from landing at basement to landing at seventh floor, a distance of 92 feet 2 inches.

Cables.—The elevator will be equipped with six $\frac{3}{4}$ -inch diameter wire cables of the best Swedish iron. The tensile strength of hoisting cables is about 18,000 pounds each.

Operating Device.—The elevator will be operated by straight pull tiller cable of $\frac{1}{2}$ -inch diameter for starting and stopping, which is so arranged as to give the operator perfect control of the apparatus.

Sheaves.—The main hoisting and counterbalancing sheaves will be of as large diameter as the hatchway and location of machine will admit. They will be grooved in the lathe to fit the cables, and be provided with heavy steel shafts, which run in heavy boxes, truly bored, with suitable means for oiling. All these sheaves will be supported by heavy yellow pine beams and where practical will be supported on the guide posts.

Guide Posts.—The guide posts will be made of pine, compound built, accurately planed, and will be securely fastened to each floor in the building in a substantial manner. Hard maple guides fastened to these guide posts will form a guide-way for the cage, which makes a noiseless and durable construction. The weight guides will be made of hardwood and will be securely fastened in hatchway to each floor of the building.

SAFETY APPLIANCES.

Automatic Top and Bottom Stop.—First. The automatic stop is placed on the operating cable, which stops

Head in Feet.	Pounds pressure per square inch.	DIAMETERS OF ORIFICES IN INCHES AND FRACTIONS OF AN INCH.									
		$\frac{1}{8}$ Inch.	$\frac{1}{4}$ Inch.	$\frac{3}{8}$ Inch.	$\frac{1}{2}$ Inch.	$\frac{5}{8}$ Inch.	$\frac{3}{4}$ Inch.	1 Inch.	1 $\frac{1}{4}$ Inch.	1 $\frac{1}{2}$ Inch.	2 Inch.
20	8.66	300	720	1260	1920	2760	4920	7380	11100	15120	19740
40	17.32	450	960	1800	2760	3960	6720	10920	15720	21360	27960
60	25.99	540	1200	2160	3480	4800	8580	13880	19200	26220	34260
80	34.65	620	1380	2460	3840	5580	9840	15480	22260	30800	39540
100	43.31	690	1560	2760	4320	6240	11040	17280	24900	33900	44280
120	51.98	780	1680	3000	4740	6840	12120	18960	27240	37440	48480
140	60.64	816	1860	3900	5100	7320	13020	20160	29460	39080	52320
150	64.97	840	1920	3420	5280	7620	13560	21180	30480	41460	54120
175	75.80	900	2040	3660	5700	8220	14640	22800	32880	44940	58560
200	86.63	960	2220	3900	6120	8760	15600	25020	35880	47880	62580
285	101.79	1080	2460	4320	8280	11160	17100	26760	38520	52260	68460

Gallons Discharged per Hour Through Various Sized Orifices
Under Stated Pressure.
Table No. 24.

the cage at the upper and at the lower landings, independently of the operator.

Automatic Limitation Stop.—Second. The automatic limitation stop, which stops the cage at the lower and upper landings in case the regular operating cable or lever device should get disarranged. Its action not only prevents an accident or damage to the cage that might result thereby, but it also protects the lifting cables from injury arising from overwinding.

Safety Brake.—Third. The safety brake is controlled by the operating cable and automatic stop, and is applied whenever the current is shut off, holding the cage at any desired point.

Slack Cable Stop.—Fourth. The slack cable stop, which stops the machine and thus prevents the unwinding of the cables should the cage meet any obstruction in descending.

Safety Grip.—Fifth. The platform will be fitted with bottom eccentric steel safety grips, which are intended to grip the guides and prevent the fall of the platform in case of the breaking or slacking of the cables.

Elevator will be equipped with safety speed governor.

Capacity.—The elevator will have a lifting capacity of 5,000 pounds, exclusive of weight of cage, at a speed of 90 feet per minute.

Preparing the Building.—You are to prepare the hatchways, and to prepare suitable room for the power; to do all cutting of walls; to furnish proper supports in place for guide posts and sheave beams, and do all painting except machinery. Should the roof be too low to allow the cage to travel to top landing, you are to make such changes in the roof as may be necessary to admit the sheaves and beams and to properly protect same.

HORSE POWER TRANSMITTED BY HEAVY DOUBLE BELT.

WIDTH OF BELT IN INCHES.	VELOCITY IN FEET PER MINUTE.										
	800	1200	1600	2000	2400	3200	3600	4000	4400	4800	5600
	HORSE POWER TRANSMITTED.										
2	4½	6¾	9	11½	13½	18	20½	22½	24½	27	31½
4	9	13½	18	22½	27	36	40½	45	49½	54	63
6	13½	20½	27	33½	40½	54	60½	67½	74½	81	94½
8	18	27	36	45	54	72	81	90	99	108	126
10	22½	33½	45	56½	67½	90	101½	112½	123½	135	157½
12	27	40½	54	67½	81	108	121½	135	148½	162	189
14	31½	47½	63	78½	94½	126	141½	157½	173½	189	220½
16	36	54	72	90	108	144	162	180	198	216	252
18	40½	60½	81	101½	121½	162	182½	202½	222½	243	283½
20	45	67½	90	112½	135	180	202½	225	247½	270	315
24	54	81	108	135	162	216	243	270	297	324	378
30	67½	101½	135	168½	202½	270	303½	337½	371½	405	472½
36	81	121½	162	202½	243	324	364½	405	445½	486	567
40	90	135	180	225	270	360	405	450	495	540	630
44	99	148½	198	247½	297	396	445½	495	544½	594	693
48	108	162	216	270	324	432	486	540	594	648	756

These calculations are based on first-class belting, made from backs of Pure Oak Tanned Leather, run under ordinary conditions and on pulleys of fair and equal size.

When the driven pulley is smaller, the power transmitted will be as much less than the above as that part of the surface of the driven pulley, which is covered by the belt, is less than half its surface.

Table No. 25.

You are to bring the power wires into the building within six feet of the motor and connect the same to our motor switch. The basis of this contract is that the current shall be constant potential, with 500 volts pressure at the motor, and it is a part of your contract to apply the current to the motor, as above specified. It is also understood you are to be responsible for the safety of the machinery after being delivered at building.

Guarantee.—We hereby **guarantee** the machinery, and all parts of the elevator specified in this contract, to be of the quality and description named herein, and to do the service specified herein, and we agree to make good any repairs on the engine and machinery or any part of the elevator which may be made necessary by any defective material or workmanship within one year from the date of completion.

SPECIFICATIONS FOR AN ELLISON SCREW GEAR POWER FREIGHT ELEVATOR.

Description.—We propose to furnish and erect complete, in building No. of our latest improved and best make of Worm Gear Power Elevators, of 2,000 pounds capacity, arranged for freight service, to be operated by power furnished, and to travel from first floor to third floor, a distance of about 23 feet, at a speed of 40 feet a minute, according to the following detail specifications:

Machine.—The machine is fitted on iron frame to suspend from the ceiling.

Winding Drum.—The winding drum is cast iron, 32-inch diameter, smoothly turned and grooved to receive two hoisting cables.

Worm Wheel.—The worm wheel will be cast iron,

HORSE POWER OF IRON AND STEEL SHAFTS
FOR GIVEN DIAMETER AND SPEED

Diameters of Shaft in Inches	REVOLUTIONS PER MINUTE									
	100	125	150	175	200	225	250	300	350	400
1¼	2.4	3.1	3.7	4.3	4.9	5.5	6.1	7.3	8.5	9.7
1½	4.3	5.3	6.4	7.4	8.5	9.5	10.5	12.7	14.8	16.9
1¾	6.7	8.4	10.1	11.7	13.4	15.1	16.7	20.1	23.4	26.8
2	10.0	12.5	15.0	17.5	20.0	22.5	25.0	30.0	35.0	40.0
2¼	14.3	17.8	21.4	24.9	28.5	32.1	35.6	42.7	49.8	57.9
2½	19.5	24.4	29.3	34.1	39.0	44.1	48.7	58.5	68.2	78.0
2¾	26.0	32.5	39.0	45.5	52.0	58.5	65.0	78.0	87.0	105.0
3	33.8	42.2	50.6	59.1	67.5	75.9	84.4	101.3	118.2	171.8
3¼	43.0	53.6	64.4	75.1	85.8	96.6	107.3	128.7	150.3	214.4
3½	53.6	67.0	79.4	93.8	107.2	120.1	134.0	158.8	187.6	214.4
3¾	65.9	82.4	97.9	115.4	121.8	148.3	164.8	195.7	230.7	243.6
4	80.0	100.0	120.0	140.0	160.0	180.0	200.0	240.0	280.0	320.0
4¼	113.9	142.4	170.8	199.3	227.8	256.2	284.7	341.7	398.6	455.6
5	158.3	195.3	234.4	273.4	312.5	351.5	390.6	468.7	546.8	625.0
5½	207.9	260.0	311.9	363.9	415.9	459.9	520.0	623.9	727.9	830.0
6	270.0	337.5	405.0	472.5	540.0	607.5	675.0	810.0	945.0	1080.0
6¼	343.3	429.0	514.9	600.7	686.5	772.4	858.0	1029.0	1201.0	1372.0
7	428.8	535.9	643.1	750.3	847.5	964.7	1071.9	1286.0	1500.0	1695.0
8	640.0	800.0	960.0	1120.0	1280.0	1440.0	1600.0	1920.0	2240.0	2560.0

Table No. 26.

26-inch diameter, 3-inch face, the cogs of which will be cut on the gear cutting machine.

Worm.—The worm will be cast steel, cut from the solid in engine lathe, 5½-inch diameter, 1½-inch pitch.

Worm Gear Case.—The worm gear case and barrel will be in one piece, with a tight stuffing-box; this forms an oil chamber, thereby having the gears always thoroughly lubricated.

Anti-Friction Ball Bearing.—The worm shaft is fitted with an anti-friction ball bearing to take the end thrust; this ball bearing runs in a separate oil chamber, so arranged as to greatly reduce the friction of the machine and prevents heating. In case of accident this ball bearing can be easily removed and repaired or replaced with a new one.

Safety Brake.—The safety brake is so arranged as to be automatically applied whenever belts are on loose pulleys, and released when either belt is shifted on tight pulley. The safety brake will be so arranged that it can be adjusted to the wear and work by means of a set-screw and lock-nut, and can be adjusted as well when machine is in motion as when at rest.

Automatic Stop.—The automatic stop forms part of the machine proper, and is so arranged as to stop it and apply the safety brake when the cage reaches either the top or bottom landings, independent of the starting and stopping cables. This prevents the winding drum from making more than the necessary revolutions to carry the cage to the bottom or top of lift.

Slack Cable Stop.—Our improved slack cable stop prevents the unwinding of the cables. Should the cage meet with any obstructions in its descent, then this stop will shift the belts, apply the safety brake, stop the cage at once, and prevent accidents that might occur.

Countershaft.—The countershaft will be of proper diameter and length, and provided with necessary hangers and pulleys, suitable size to run elevator proper speed.

Belting.—The driving belt from to countershaft will be endless, wide. The two elevator belts from countershaft to elevator pulleys wide. All to be proper length. To be furnished by you.

Driving Pulley.—The driving pulley on line shaft will be .. diam. x .. face. To be furnished by you.

Guarantee.—We guarantee our machinery in every part to be free from defects of either material or workmanship, and equal to, if not superior, in strength, durability and light running, to any of its class made; and should any such defects appear within one year, we will repair or make same good free of cost to you.

Preparing Building.—You are to prepare or provide the necessary hatchways free of expense to us, as also any doors, gates or enclosures. If there is not sufficient height in upper story to permit of placing the sheaves under the roof, and allow cage to reach top floor, it will be necessary to place them above the roof, in which case you enclose or cover same. To avoid this, the top story should not be less than 12 or 14 feet high.

Pulleys.—The three pulleys will be cast iron, 18-inch diameter by $4\frac{1}{2}$ -inch face, and will be turned true and balanced. The loose pulleys will be provided with capacious oil chambers, bronze brushes, and a greatly improved self-oiling apparatus. By this combination we secure greater durability than by any other known method. The lifting pulley is of larger diameter than the loose pulleys, thus preventing unnecessary strain on the machine and belts when the winding drum is not in motion.

Cage.—The cage will be made of seasoned hardwood

timber, with all needed iron work and braces, and arranged for guide posts at sides of hatchways. The platform will be about 7x8 feet, or proper size to suit present hatchways in building.

Guide Posts.—The guide posts will be yellow pine, 6'x6' solid, and on these will be securely fastened the guide strips on which the cage guides will run smoothly.

Counter Balance and Guides.—The counter balance weight will be cast iron, made in sections and detachable, and of sufficient weight to balance cage, leaving only weight enough to bring cage down when empty.

The weight guide strips will be white pine, $2\frac{1}{2}$ x $3\frac{1}{2}$ inches, with a groove in one side to guide the weight.

Sheaves.—The overhead sheaves will be heavy cast iron of large diameter, smoothly turned in groove, and fitted with heavy steel shafts and babbitted boxes, and supported by suitable timbers.

Cables.—The cage will be supported by two $\frac{5}{8}$ x19 Swede's iron wire cables for hoisting, each of which is capable of standing a strain of tons. The starting and stopping arrangements will be operated by one $\frac{1}{2}$ x19 Swede's iron wire cable.

The counter balance weight will be supported by one $\frac{5}{8}$ x19 Swede's iron wire cable. All cables to be of best quality made.

Our elevators are provided with the following safety appliances:

Safety Pawls.—The safety pawls are attached to the cross beam of the cage, and are operated by a steel spring. In the event of the parting of the lifting cables, or if the cage meets with any obstructions in its descent, these engage with the uprights and securely lock the cage.

Stop Buttons.—The stop buttons are attached to the starting and stopping cables to stop the cage at the top and bottom landing, independent of the operator.

CHAPTER XXVIII.

THE STEAM ENGINE INDICATOR.

Definition.—The indicator is an instrument used to indicate the amount of **pressure** in the cylinder of an engine, and also to indicate the exact **location** of the piston when that pressure exists. From this can be told not only the **distribution** of the steam pressure throughout the stroke of the piston, but also the **action** of the valve gear.

The obtaining of this knowledge by means of the indicator has been of the greatest assistance in the development of the steam engine.

Construction.—This instrument as invented by Watt consisted simply of a small piston working in a cylinder, which cylinder was a miniature of the larger cylinder whose performance was desired to be known.

The movement of the spring due to the steam pressure on it, was shown by the tracing of a pencil on a piece of paper made to move simultaneously with the piston of the engine. Later, a drum on which the paper was attached was adopted.

With the single exception of **multiplying** the movement of the indicator spring by using a lever, which permitted a stiffer spring to be used, there has been no change in the general construction of the indicator since its invention.

By using a stiffer spring than was employed by Watt, the movement of the indicator piston was lessened, which therefore required its movements to be multiplied, i. e., **increased**, so that the diagram, or card as it is called, made by the movement of the pencil on the paper, would be increased to a sufficient size so as to be readily understood.

The indicator is therefore an instrument which is employed to give a correct idea of all that takes place in the cylinder.

It consists of a small cylinder accurately bored out and fitted with a piston, which works in the cylinder with little or no friction, and yet is practically steam-tight.

The piston has an area of just one-half of a square inch, and its motion or travel in the cylinder, is only $25/32$ of an inch.

The piston rod is connected to a pair of light levers, so linked together that a pencil carried at the center of the link moves in nearly a straight line through a maximum distance of $3\frac{1}{8}$ inches. A spiral spring placed in the cylinder above the piston resists the motion of the piston, and the elasticity of this spring is such that each pound of steam pressure on the piston causes the pencil to move the fractional part of an inch. As the steam pressure that exists each instant in the cylinder of the engine is the same as the pressure on this spring, the pencil, which records the movements of the spring, will accurately record the **pressure** in the cylinder. This is the fundamental principle on which all indicators operate.

The pencil is usually made of a piece of pointed brass wire which makes a well defined line upon the paper especially prepared for indicator work.

This paper is wound around the drum, which has a diameter of 2 inches, and is capable of a semi-rotary motion upon its axis to such an extent that the extreme length of the diagram may be $5\frac{1}{4}$ inches. While these dimensions are those of the most generally used indicator, they are slightly varied for different character of work, the drum frequently being made only $1\frac{1}{2}$ inches.

Motion is given to the drum in one direction, during the forward stroke of the piston, by means of a cord connected indirectly to the cross-head of the engine, the drum being brought back again during the return stroke of the piston, by the action of a coiled spring at its base.

The **upper** side of the piston is open to the atmosphere, while the **lower** side may be put in communication either with the atmosphere, or with either end of the engine cylinder.

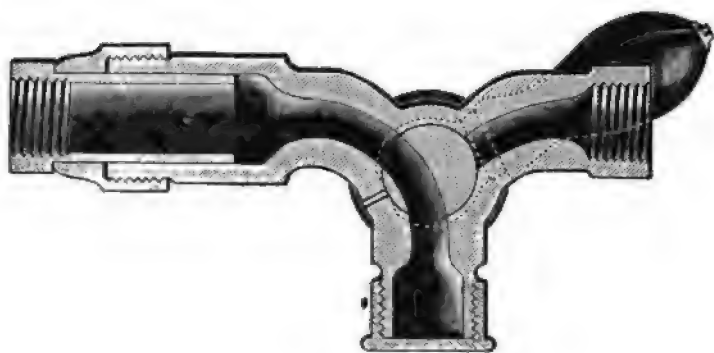
This is done by means of a three-way cock, such as shown in Fig. 262, a quarter turn of the handle placing either end of the cylinder in connection with the indicator.

When **both** sides of the piston are pressed upon by the atmosphere, there is no pressure on the spring other than the atmospheric pressure, and the pencil on being brought into contact with the moving paper describes what is known as the **atmospheric line**.

When the lower side of the piston is in communication with the engine cylinder, the pressure of the steam therein then acts upon the indicator piston; and on the pencil being pressed against the paper during a complete double stroke of the engine, the entire indicator diagram is described.

Essential Parts.—The four essential parts of the indicator are therefore; the cylinder, the spring, the piston with its connections, and the drum.

To attach the Indicator to the Engine.—All first-class engines are prepared for the indicator before leaving the factory. Should this not have been done, then **each** end of the cylinder must be drilled and tapped for a one-half inch pipe thread. The holes must be drilled into the **clearance space**, so that the piston at the ends of the stroke will not cover them. They should also be



A Three-Way Cock.
Fig. 262.

placed so that currents of steam will not reach them. The holes should be drilled into the **middle** of the clearance space, the engine being placed on dead center in order to determine the clearance.

For **horizontal** engines the holes are drilled in the side of the cylinder at each end; while for **vertical** engines, the upper head or cover and the side of the cylinder are selected for the upper and lower indicators respectively.

Where it is necessary to use only **one** indicator for both ends of the cylinder, the indicator should then be connected by side pipes, and a three-way cock used to make connection with the two ends. By this method both diagrams are taken on the same card, and with the loss of but one revolution.

Reducing Motion.—As the length of the card represents the **travel** of the engine piston, and as the length of the card is much less than the travel of the piston, since the stroke is much longer than the circumference of the drum; therefore the movement of the cross-head which actuates the drum, must be reduced to the length of the diagram. While it is not necessary to use the cross-head for the operation of the drum of the indicator, since it has many advantages for this purpose, it is generally used.

But whether the cross-head or some other part of the engine is selected, there must be a **reduction** of the movement of same to the length of the diagram, and there are several devices employed to obtain this reduced motion; such as the pantograph, lazy tongs, Brumbo pulley, reducing wheel, etc.

Uses of the Indicator.—It is principally used, (1) to measure the power of the steam engine; (2) to show the quantity of steam used per horse power for a given time;

(3) to indicate how to adjust the valve gear of the engine; (4) the vacuum obtained by the use of the condenser; and (5) the relative pressure existing between the steam in the boiler and the pressure of the steam in the cylinder.

Indicator Card or Diagram.—The tracing of the pencil on the paper of the indicator, is called a **card** or **diagram**, and is the result of the horizontal and vertical motions of the indicator. The **horizontal** movement of the paper corresponds exactly to the movement of the **piston**; as this motion is produced by the movement of the cross-head which rotates the drum by means of the cord attached to it.

The **vertical** movement of the pencil, is in exact ratio to that of the **pressure** of the steam in the cylinder of the engine.

The diagram therefore represents by its **length**, the **stroke** of the engine; and by its **height**, the steam pressure on the piston at the corresponding point of the stroke.

Suppose a valve has **no lap**, the steam would then be admitted to the cylinder during the **whole stroke**, that is, one end of the engine cylinder is in communication with the boiler during the **entire** stroke of the piston. Now, if the indicator is placed in communication with the cylinder during this stroke of the piston, the diagram or card will show a **rectangle**, as can be seen from the following illustration.

If we draw two lines at right angles to each other, the horizontal line will represent the **volume** of the steam, while the vertical line will represent the **pressure**. As both the volume and the pressure will remain the **same** during the entire stroke of an engine taking steam full stroke, these lines will be perfectly **straight**, and at

right angles to each other. In Fig. 263 is shown the diagrams of an engine taking steam at full stroke.

There are but few modern engines that take steam full stroke, it being too wasteful of steam. Steam is admitted during **part** only of the stroke, the communication to the boiler being then cut off, and the steam in the cylinder being allowed to **expand** as the piston moves forward until it fills the entire volume of the cylinder. What then takes place in the cylinder is represented graphically by the diagram shown in Fig. 263.

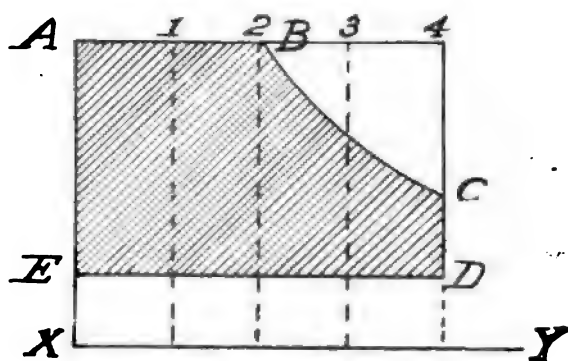
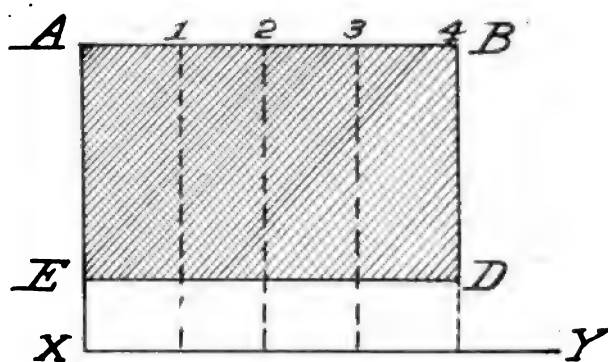
Steam is admitted to the cylinder until the piston reaches the point B, which represents one-half the volume of the cylinder. Then the cylinder is half full of steam, but from this point on as no more steam is admitted, and as the volume continues to **increase**, the pressure must **diminish**. The diminution in the pressure is shown by the curved line B. C., which is called the **expansion line**. This curve should be almost an equilateral hyperbola.

The exhaust valve opens at the point C, releasing the pressure acting on the piston; and in consequence the pressure is also released on the indicator spring, thereby causing the pencil to make the vertical line C. D.

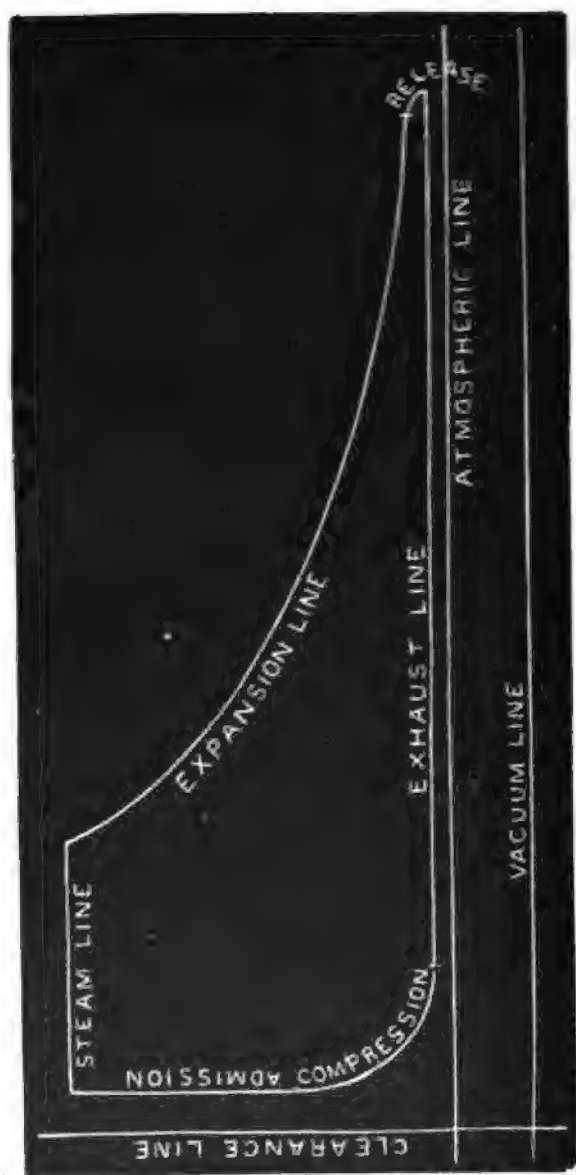
The piston then starts on its return stroke, and as the only back-pressure acting on it is the pressure of the **atmosphere**, the pencil traces the line D. E., called the **back-pressure line**.

As there is no lead to the valve, and no compression, the line D. E. will meet the line E. A. at a right angle. Should there have been **compression**, then the pressure would have produced a curved line, such as shown in Fig. 264, the curve there shown being called the **compression line**.

In Fig. 264 is shown an **ideal** diagram, in which all



Diagrams of Full and Part Stroke.
Fig. 263.



An Ideal Indicator Diagram.
Fig. 264.

the lines that are traced during the forward and return stroke of the piston, are given their usual designation.

Admission Line.—This line shows the **rise** of the pressure due to the admission of steam to the cylinder. This line will be **vertical** if the steam is admitted **quickly** by the valve when the engine is nearly on center. Should the line curve to the left or right from a vertical or perpendicular position, it is due to the valve opening **too late or too early**, as the case may be.

Steam Line.—This line is drawn during the time the valve admits steam to the cylinder. It will be a **horizontal** line unless the steam is **wire-drawn**, in which event it will be **diagonal**, that is, it will have a **downward** inclination.

Cut Off.—The point at which the admission of steam is stopped by the closing of the valve, is shown by the sudden drop in the steam line. Since the valve closes **slowly** this point will be rounded, and at times hard to detect, but its position can always be determined by remembering it is the point where the curve **changes** from concave to convex.

Expansion Curve.—This line shows the **fall** in pressure as the steam expands while the piston moves towards the end of the stroke. As the volume occupied by the steam in the cylinder **increases**, the pressure **decreases**.

Point of Release.—This is the point at which the exhaust valve opens. It is always a rounded point due to the slow action of the valve in opening. This exhaust curve begins a little before the end of the forward stroke, which is also due to the slow action of the valve in opening.

Exhaust Line.—This line, or curve, shows the loss in pressure when the valve opens to exhaust.

Back Pressure Line.—This line shows the back-pressure against which the piston acts during the **return** stroke.

Exhaust Closure.—This is the point where the valve closes to the exhaust, and **compression** begins.

Compression Curve.—This line shows the **rise** of pressure due to the compression of the steam remaining in the cylinder after the valve has closed to the exhaust.

Atmospheric Line.—This line is drawn after the diagram has been made and the connection to the engine is closed, and both sides of the piston of the indicator are open to the atmosphere. This line therefore shows the **atmospheric pressure**, which is then alone acting on the indicator piston. It is the same as the **zero** of the steam gauge.

The **height** of the back-pressure line above this line, shows the amount of the back-pressure in addition to the atmospheric pressure acting on the piston of the engine.

The Zero or Vacuum Line.—This is the line of **absolute** vacuum, and is drawn below and parallel to the atmospheric line. The distance between the atmospheric line and this line therefore represents 14.7 pounds pressure.

Clearance Line.—This line is drawn perpendicular to the line of absolute vacuum, and at a distance from the end of the diagram equal to the same percent of the **length** of the diagram as the clearance **volume** is of the piston displacement.

Practical Diagrams.—The actual shape of practical diagrams is always different from the ideal diagram, such as shown in Fig. 264, which is a **theoretical** diagram.

This is due to the valve not opening and closing quickly, thereby causing rounded corners or points; also the ports offer some resistance to the passage of the

steam, thereby causing the horizontal lines to be deflected from their course. As the back-pressure in non-condensing engines is always **more** than atmospheric, the back-pressure line is always **above** the atmosphere line. In condensing engines, the vacuum is never absolute, thereby causing the vacuum line always to be **above** the zero line.

Practical Lines.—A few illustrations are here given so that the student may familiarize himself with diagrams most frequently seen in actual work.

Early Admission.—The admission line 1-2, diagram 1, Fig. 265, indicates **too early** admission, as this line curves to the left.

Late Admission.—The steam line 1-2-3, diagram 2, indicates **too late** admission, this line curving to the right.

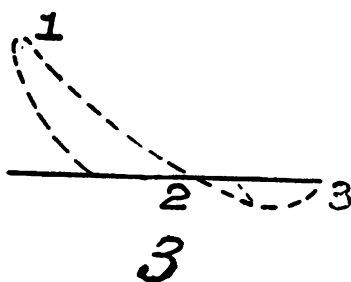
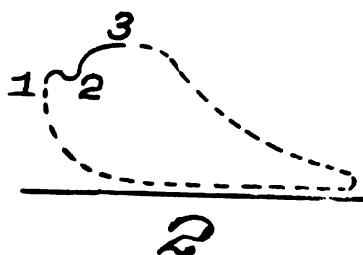
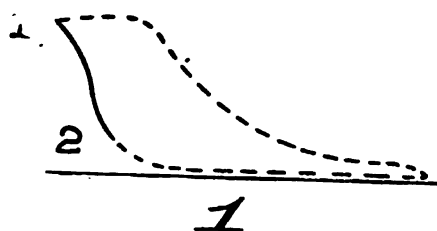
Early Cut Off.—The expansion line 1-2-3, diagram 3, indicates too early cut off, the pressure in the cylinder becoming less than the atmospheric pressure before release; thereby producing a partial vacuum in the cylinder formed by the rapid cylinder condensation. This is shown by the expansion line running **below** the atmospheric line.

Late Cut Off.—The steam line 1-2, diagram 4, Fig. 266, indicates **too late** cut off, as this line shows that admission extended during full half stroke of the piston. This diagram also indicates **late release**.

Early Release.—The line 1-2, diagram 5, indicates that the point 1 of release was too early.

Late Release.—The line 1-2-3, diagram 6, indicates too late release, the expansion having been continued to the point 1, and the release not taking place until the piston was on its **return stroke**.

Early Compression.—The line 1-2-3, diagram 7, Fig. 267, indicates too early compression, the pencil being



Diagrams 1-2-3 Showing Early Admission.
Fig. 265.

forced above the initial or boiler pressure, and falling back as the piston of the engine commences its return stroke; thereby forming the **loop** shown in the diagram.

Little Compression.—The compression line 1-2, diagram 8, indicates too little compression, as this curve should be much more rounded.

No Compression.—In diagram 9 there is shown no compression whatever, there being a corner or right angle at 1, in place of the usual curve.

Choked Admission.—The admission line 3-1, diagram 10, Fig. 268, indicates by its slanting to the right that the admission was late, due to the valve opening late. The steam line 1-2 indicates by its slant **downward**, an insufficient steam supply as the piston moves forward. This is due to the choking, or wire-drawing, of the steam from having too small ports.

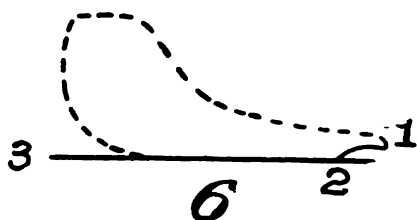
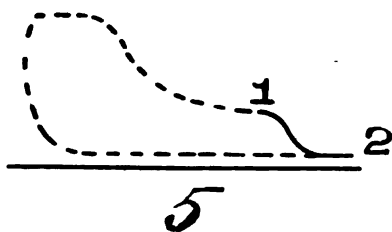
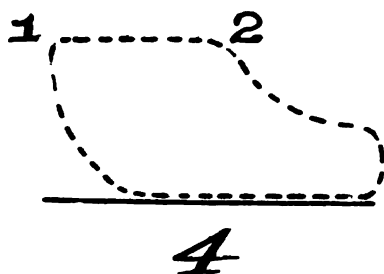
Leaky Cut-Off.—The steam line 1-2, diagram 11, indicates a leaky cut off, the point of cut off at 1 not being clearly defined.

Choked Exhaust.—The exhaust line 1-2, diagram 12, indicates a choked exhaust, as the exhaust line indicates excessive back-pressure on the return stroke of the piston, thereby making the point 2 at which release takes place much too high.

Excessive Back Pressure.—The exhaust line 1-2, diagram 13, Fig. 269, indicates excessive back-pressure, the line being too high above the atmospheric line, which continues the whole length of the return piston, there being no fall or curve at the release point 2.

Double Admission.—The steam line 1-2-3, diagram 14, indicates **double admission**, due to **leakage** or **irregularity** of the valve motion.

Eccentric Slipped Back.—In diagram 15, the eccentric is shown slipped back. All the lines show the events



Diagrams 4-5-6 Showing Late Cut Off.
Fig. 266.

in the steam distribution to be late. Instead of the admission line being vertical, it curves to the right.

Eccentric Too Far Ahead.—In diagram 16, Fig. 270, the eccentric is too much ahead of the crank, i. e., the angle of advance is too great, causing all the events in the steam distribution to take place **too early**.

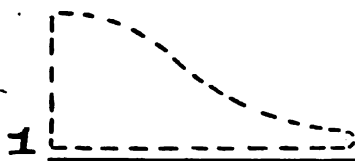
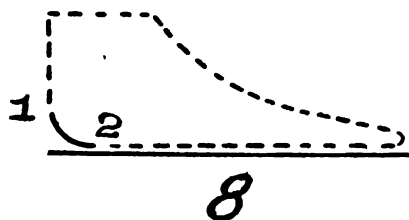
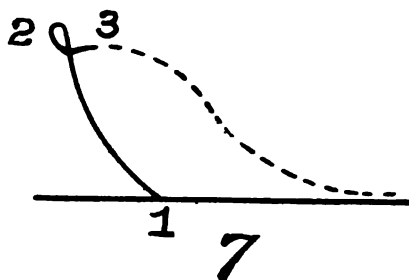
The admission line 1-2 curves to the left; there is also but little of a steam line, while the release is so early that there is **no** exhaust line.

Indicator Inertia.—The line 1-2-3, diagram 17, indicates by the **waves** in the curve, the inertia of the indicator spring. The line 1 in diagram 18 also indicates inertia.

In Fig. 271, diagram 1, the line shown comprises **both** the compression and admission lines. This admission line indicates that the pressure runs up suddenly to full pressure, the line being perpendicular as it should be. To secure this line the steam valves must open fully before the piston begins its stroke. Should the valve open too soon, this line will curve to the left; if on the contrary the piston begins its stroke before the valve opens, then the pressure in the cylinder will not be full pressure, and this line will curve to the right. The amount of **lead** will determine to a great extent the character of this line.

Should there be considerable lead, thereby increasing the compression; then the compression curve will have the appearance shown in diagram 2.

Diagrams 3 and 4, indicate that the piston started on its return stroke **before** the valve opened to admit steam, thereby curving the admission line to the right from a perpendicular position, showing that the valve opened too late. The angle of advance of the valve must therefore be **increased**.



Diagrams 7-8-9 Showing Compression.
Fig. 267.

In Fig. 272 is shown several more types of admission and compression lines.

In diagrams 1 and 2, the **loop** in the compression line is caused by the piston starting before the valve opens, causing the compression to run up and then suddenly fall back as the piston moves forward.

In diagrams 3 and 4 are from cards taken off a high speed engine with a shaft governor. The loop in these diagrams is caused in the same way as previously shown, i. e., by the compression becoming **greater** than the initial or boiler pressure, and suddenly **decreasing** when the valve opened.

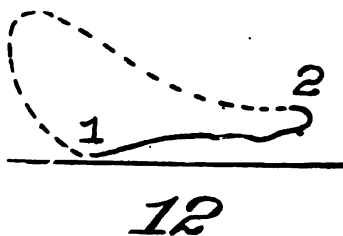
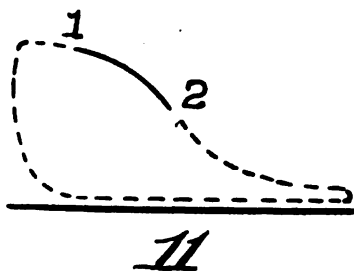
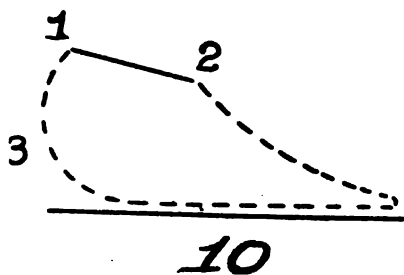
In Fig. 273, the compression lines shown are due to faulty valve setting. The loop, or sharp turn in diagram 1 is due to a sudden drop in pressure from the valve **lifting** from its seat, or some similar cause.

In diagram 2 there is no compression, which is due to the exhaust valve failing to close in time to cushion the steam, thereby causing a possible "pounding" of the engine.

The line in diagram 3 is also caused by failure of the exhaust valve to close at the proper time.

The loop in diagram 4 can be caused by the eccentric slipping, but it is more probably caused by failure of the exhaust valve to close until the piston was on its **forward** stroke. The exhaust valve in this case remained closed so long that the pressure forced this line below the exhaust line, at which point the admission valve opened and the admission line ran up, thus forming the loop.

In Fig. 274, the sharp point in diagram 1 indicates too much lead, causing the pressure to run up above the initial pressure and causing the steam line to quickly drop, thereby forming the sharp point or corner.



Diagrams 10-11-12 Showing Choked Admission; Leaky Cut-Off;
Choked Exhaust.
Fig. 268.

The loop shown in diagram 2 indicates too early cut off, thereby permitting the pressure to drop below the atmospheric pressure. This can be remedied by either **reducing** the boiler pressure, or making a later cut off. The latter is not advisable, as it will lower the **efficiency** of the engine. The defects in the other diagrams of this figure are apparent.

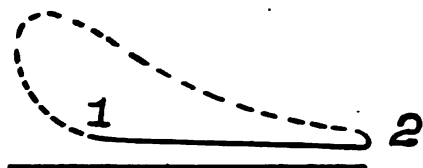
Valve Setting with Indicator.—The diagram shown in Fig. 275 indicates too early admission. The cut off, release and compression are all too early. We therefore presume this card is taken off a plain slide valve engine, and that the valve has too much angular advance, and hence it must be decreased.

In Fig. 276 the admission is **late**, as well as all the other events in the steam distribution. We therefore must **increase** the angular advance of the valve until the admission line is perpendicular to the atmospheric line.

In Fig. 277 is shown the diagram of a valve having **too late** a cut off, thereby causing a very high pressure at release.

By making this valve cut off **earlier**, more expansion can be obtained from the steam, and the pressure at release also becomes much **less**.

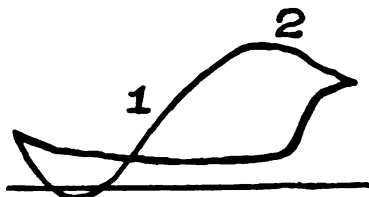
To Find the Area of Cards.—As we have seen, in order to find the **horse power** of an engine it is necessary to know the **mean effective pressure**, that is, the **average** pressure acting on the piston throughout the stroke. It is for finding this mean effective pressure that the indicator is mostly used by engineers. This mean effective pressure is equal to the **area** of the indicator diagram divided by the **length**. The **length** is easily found by measuring it, but it is much more difficult to find the **area**, as the card assumes so many different shapes.



13



14



15

Diagrams 13-14-15 Showing Excessive Back Pressure; Double Admission; Eccentric Slipped Back.

Fig. 269.

Area.—The area of the indicator card can be found in two ways, viz.: (1) by dividing the diagram into sections, and (2) by the use of a planimeter.

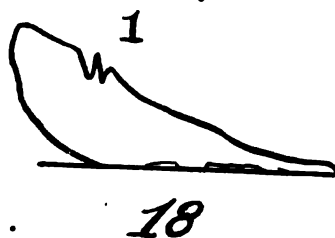
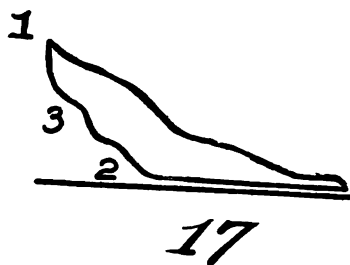
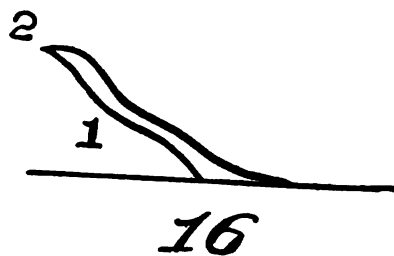
As the former method is rarely used, and is only an approximate method, it will not be considered.

Planimeter.—There are several planimeters and averaging instruments in common use for determining the mean effective pressure of indicator cards. All these instruments are constructed upon the same general principles.

DESCRIPTION OF PLANIMETER AND PANTOGRAPH.

The Coffin Planimeter.—This instrument is operated by moving a tracer, with which it is fitted, over the line of diagram, recording the area upon a graduated wheel, as is illustrated in Fig. 278.

Operation.—In using the Coffin planimeter, the grooved metal plate, I, is first connected to the board upon which the apparatus is mounted, in the position shown in the cut, being held in place by a thumbscrew applied from the back side. The indicator card is then placed under the clamps C and K, which may be sprung away from the board a sufficient amount to allow the card to be introduced, and the card is moved toward the left into such a position that the atmospheric line is near to and parallel with the lower edge of the stationary clamp C, while the extreme left-hand end of the diagram is even with the perpendicular edge of the clamp. The movable clamp K, which is fastened at the bottom to a sliding plate, is then moved toward the left, till the vertical beveled edge just touches the extreme right-hand end of the diagram. The diagram shown in the cut represents the proper location which should exist when



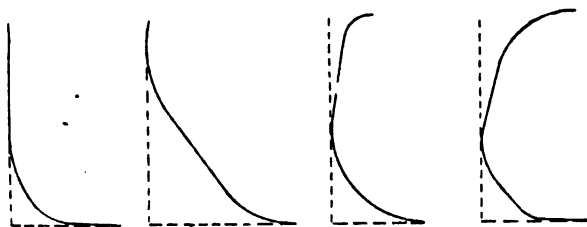
16-17-18 Showing Eccentric Too Much Ahead; Indicator Inertia.

Fig. 270.

these preliminary adjustments have been completed. The slide at the bottom of clamp K fits closely, so that the application of a slight pressure with the thumb or finger is required to displace it.

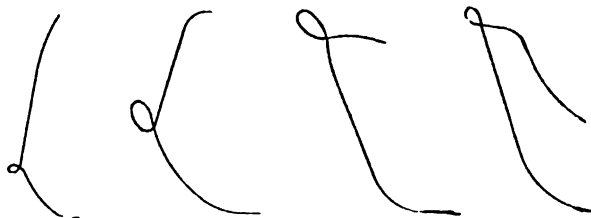
The beam of the instrument is next placed on the board, with the pin at the lower end resting in the groove I, and the weight Q applied to the top of the pin so as to keep it securely in place. The tracer O is moved to the right-hand end of the diagram and set at the point D, on the line of diagram, where the clamp K and the diagram touch each other. Here a slight indentation is made in the paper by pressing the finger on the top of the tracer, and this serves as a starting point. The graduated wheel is next turned so as to bring its zero mark to the zero mark on the vernier. The instrument is now ready for operation. The tracer O is carefully moved over the line of the diagram, in the direction of motion of the hands of a watch, and continued till a complete circuit is made and the tracer finally reaches the starting point D. Keeping the eye on the wheel, the tracer is now moved upward by sliding it along the edge of the clamp K, until the reading on the wheel returns to zero. Another light indentation is made on the paper to mark the new position which the tracer occupies. This point is represented at A in the cut. The instrument is now moved away, the clamp pushed back, and the distance between the two points D and A is measured with a scale corresponding to the number of the spring used in the indicator. The distance thus found is the mean effective pressure, expressed in pounds per square inch of piston.

The **Coffin planimeter** determines the desired result without computation, but it may be used also for determining the area enclosed by the diagram. This area is



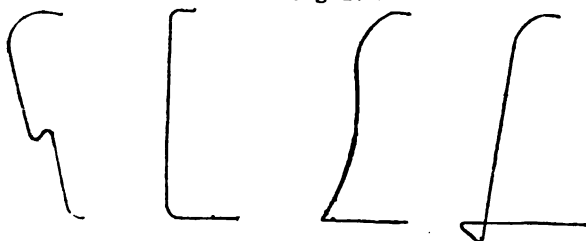
Admission and Compression Lines.

Fig. 271.



Admission and Compression Lines.

Fig. 272.



Faulty Valve Setting.

Fig. 273.

given by the reading on the graduated wheel, when the circuit of the diagram has been made and the tracer reaches the starting point, D. The wheel has fifteen main divisions, each of which represents one square inch of area. Each division has five subdivisions, each subdivision representing one-fifth, or two-tenths, of a square inch of area. The vernier scale enables the subdivisions to be read to fiftieths, each of these fiftieths, therefore, representing two one-hundredths of a square inch. Having obtained the area in this manner, the mean effective pressure can be computed therefrom, if desired, by dividing the number of the spring representing the pressure per inch in height by the length of the diagram (inches) and multiplying the quotient by the area (square inches). In first placing the indicator card under the clamps, care must be taken to have the ends of the diagram set a little away from the edge of the clamp, so as to allow for one-half the diameter of the tracer, and to bring the center of the tracer over the center of the line of the diagram.

LAZY TONGS OR PANTOGRAPH.

In Fig. 279 is shown one of the most generally used devices in indicator work for reducing the engine stroke.

There are various devices used to reduce engine strokes to conform to the travel of the drum of an indicator not equipped with the reducing motion. The above cut, one-sixth actual size, is one of the appliances frequently used to obtain the necessary motion (on a reduced scale between the paper drum and the engine cross-head. This device is pivoted at the end (B) by a stud and winged thumb nut to a block of wood or angle iron secured to the floor of the engine room, while the end (A) is fitted in a suitable piece secured to the cross-head of the engine. The actuating cord from the indi-

1



2



3



4



5



Diagrams Showing Faulty Valve Setting.
Fig. 274.

cator is attached to the cord pin (E) on the cross-bar (C D). This cross-bar may be moved in different positions with relation to the center (B) by changing the screws (C and D), and the cord-pin (E) must always be placed in a line with the centers (A and B). The position of the cross-bar (C D) in relation to (B) determines the length of travel of the cord-pin (E), and consequently the length of the diagram.

This lazy tong can be used to obtain any desired reduction of motion of the engine piston, of various length strokes up to 72 inches.

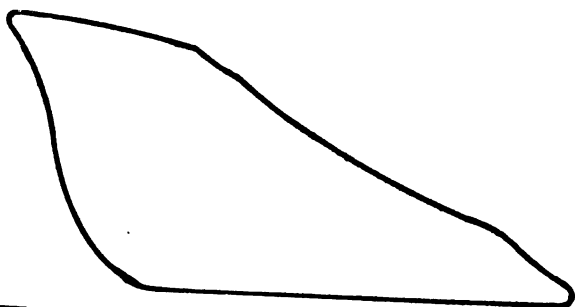
THE CROSBY STEAM ENGINE INDICATOR.

Construction.—Fig. 280 shows the design and arrangement of the parts of the Crosby steam engine indicator.

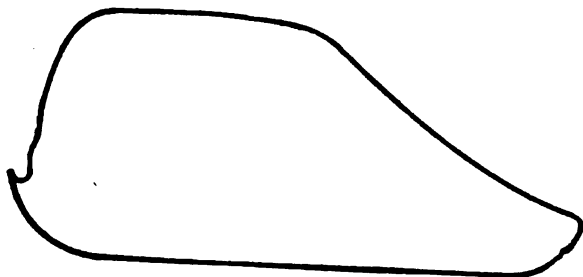
Part 4 is the cylinder proper, in which the movement of piston takes place. It is made of a special alloy, suited to the varying temperatures to which it is subjected, and secures to the piston the same freedom of movement with high pressure steam as with low; and as its bottom end is free and out of contact with all other parts, its longitudinal expansion or contraction is unimpeded, and no distortion can take place.

Between the parts 4 and 5 is an annular chamber, which serves as a steam jacket; it will always be filled with steam of nearly the same temperature as that in the cylinder.

The piston, 8, is formed from a solid piece of the finest tool steel. Its shell is made as thin as possible consistent with proper strength. It is hardened to prevent any reduction of its area by wearing, then ground and lapped to fit (to the ten-thousandth part of an inch) a cylindrical gauge of standard size. Shallow channels



Too EARLY ADMISSION
FIG. 275.



Too LATE ADMISSION.
FIG. 276.



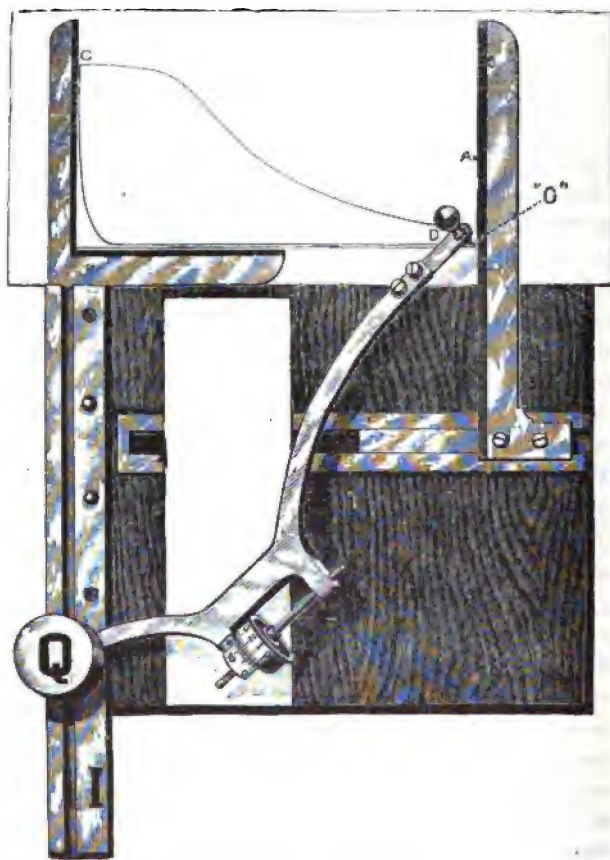
Too LATE CUT OFF.
FIG. 277.

in its outer surface provide a steam packing, and the moisture and oil which they retain act as lubricants, and prevent undue leakage by the piston. The transverse web near its center supports a central socket, which projects both upward and downward; the upper part is threaded inside to receive the lower end of the piston rod; the upper edge of this socket is formed to fit nicely into a circular channel in the under side of the shoulder of the piston rod, when they are properly connected. It has a longitudinal slot which permits the ball bearing on the end of the spring to drop to a concave bearing in the upper end of the piston screw 9, which is closely threaded into the lower part of the socket; the head of this screw is hexagonal, and may be turned with the hollow wrench which accompanies the indicator.

The piston rod, 10, is of steel, and is made hollow for lightness. Its lower end is threaded to screw into the upper socket of the piston. Above the threaded portion is a shoulder having in its under side a circular channel formed to receive the upper edge of the socket, when these parts are connected together. When making this connection the piston rod should be screwed into the socket as far as it will go, that is, until the upper edge of the socket is brought firmly against the bottom of the channel in the piston rod. This is very important, as it insures a correct alignment of the parts, and a free movement of the piston within the cylinder.

The swivel head, 11, is threaded on its lower half to screw into the piston rod more or less according to the required height of the atmospheric line on the diagram. Its head is pivoted to the piston rod link of the pencil mechanism.

The cap, 2, screws into the top of the cylinder, and holds the sleeve and all connected parts in place. Its

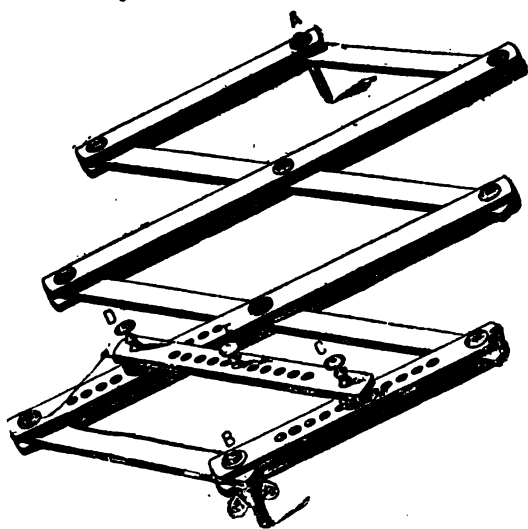


The Coffin Planimeter.
Fig. 278.

central hole is furnished with a hardened steel bushing which forms a support and a guide to the piston rod. On its under side are two threaded portions. The lower and smaller projection is screw-threaded outside to engage with the like threads in the head of the spring, and hold it firmly in place. The upper and larger projection is screw-threaded on its lower half to engage with the light threads inside the cylinder; the upper half of this larger projection—being the smooth vertical portion—is accurately fitted into a corresponding recess in the top of the cylinder, and forms thereby a guide by which all the moving parts are adjusted and kept in correct alignment.

The sleeve, 3, surrounds the upper part of the cylinder, and supports the pencil mechanism. It turns freely, and is held in place by the cap. The handle for adjusting the pencil point is threaded through the arm, and in contact with a stop screw in the plate, 1, may be delicately adjusted to the surface of the paper on the drum. It is made of hardwood in two sections; the inner one may be used as a lock-nut to maintain the adjustment.

The pencil mechanism is designed to afford sufficient strength and steadiness of movement, with the lightness; thereby eliminating as far as possible the effect of momentum, which is especially troublesome in high-speed work. Its fundamental kinematic principle is that of the pantograph. The fulcrum of the mechanism as a whole, the point of attachment to the piston rod, and the pencil point, are always in a straight line. This gives to the pencil point a movement exactly parallel with that of the piston. The movement of the spring throughout its range bears a constant ratio to the force applied, and the amount of this movement is multiplied six times at the pencil point. The pencil lever, links and pins, are all made of hardened steel; the latter—slightly tapering—



Lazy Tongs or Pantograph.
Fig. 279.

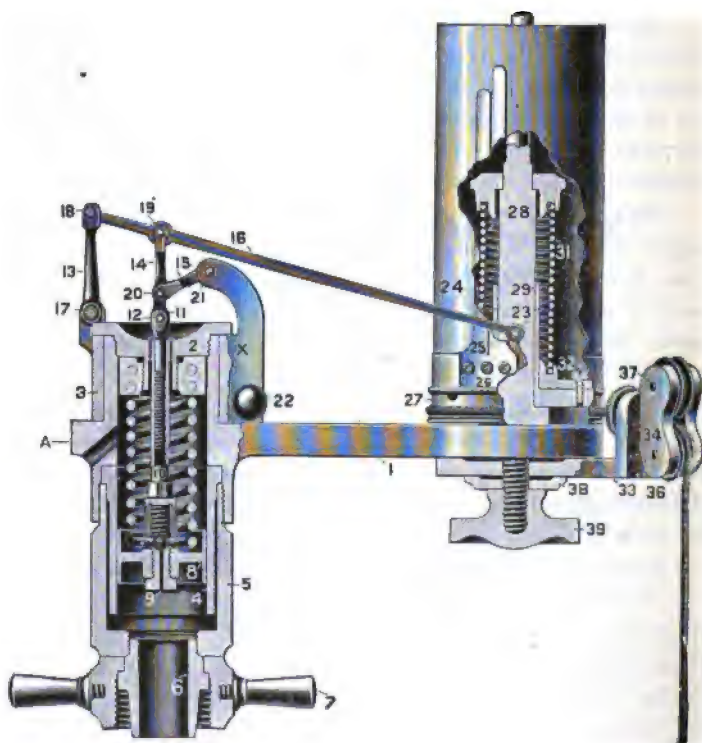
are ground and lapped to fit accurately, without perceptible friction or lost motion.

Springs.—In order to obtain a correct diagram, the movement of the pencil of the indicator must be exactly proportional to the pressure per square inch on the piston of the steam engine at every point of the stroke; and the velocity of the surface of the drum must bear at every instant a constant ratio to the velocity of the piston.

The piston spring is of unique and ingenious design, being made of a single piece of the finest spring steel wire, wound from the middle into a double coil, the spiral ends of which are screwed into a brass head having four radial wings, with spirally drilled holes to receive and hold them securely in place.

Adjustment is made by screwing them into the head more or less until exactly the right strength of spring is obtained, when they are there firmly fixed. This method of fastening and adjusting removes all danger of loosening coils, and obviates all necessity for grinding the wires—a practice fatal to accuracy in indicator springs.

At the bottom of the spring—in which lightness is of great importance, it being the part subject to the greatest movement—is a small steel bead, firmly attached to the wire. This bead has its bearing in the center of the piston, and in connection with the lower end of the piston rod and the upper end of the piston screw, *g* (both of which are concave to fit), it forms a ball and socket joint, which allows the spring to yield to pressure from any direction without causing the piston to bind in the cylinder, which is sure to occur when the spring and piston are rigidly united. It is of extreme importance that the spring be so designed that any lateral movement it may receive when being compressed shall not be communicated to the piston and cause errors in the diagram.



The Crosby Steam Engine Indicator.

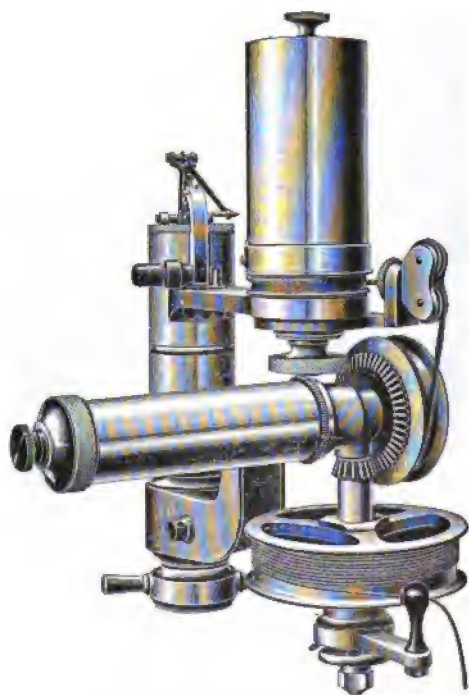
Fig. 280.

The Testing of the Spring.—The rating or measurement of the springs, both in vacuum and in pressure, is determined with great care and accuracy by special apparatus. The vacuum test is made by a powerful vacuum pump, to which is connected a mercury column marked in inches. The pressure test is by the direct action of the steam in the cylinder of the indicator and in a mercury column simultaneously operating with a capacity of three hundred pounds pressure per square inch. Suitable and ingenious electrical apparatus is so combined with these mercury columns that the ordinary division in inches of vacuum and in pounds pressure respectively are automatically marked on the test card on the indicator drum as the test of the spring proceeds. Each spring is tested in pressure to twice the capacity marked on the same.

The drum spring, 31, in the Crosby indicator is a short spiral spring. It is obvious from the large contact surfaces of a long spiral spring, that its friction would be greater than that of a short, open, spiral form, also, that in a spring of each kind, for a given amount of compression—as in the movement of an indicator drum—the recoil would be greater and expended more quickly in the spiral than in the volute form.

If the conditions under which the drum spring operates be considered, it will readily be seen, that at the beginning of the stroke, when the cord has all the resistance of the drum and spring to overcome, the latter should offer less resistance than at any other time; in the beginning of the stroke in the opposite direction, however, when the spring has to overcome the inertia and friction of the drum, its energy or recoil should be greatest.

These conditions are fully met in the Crosby indi-



The Crosby Reducing Wheel.

Fig. 281.

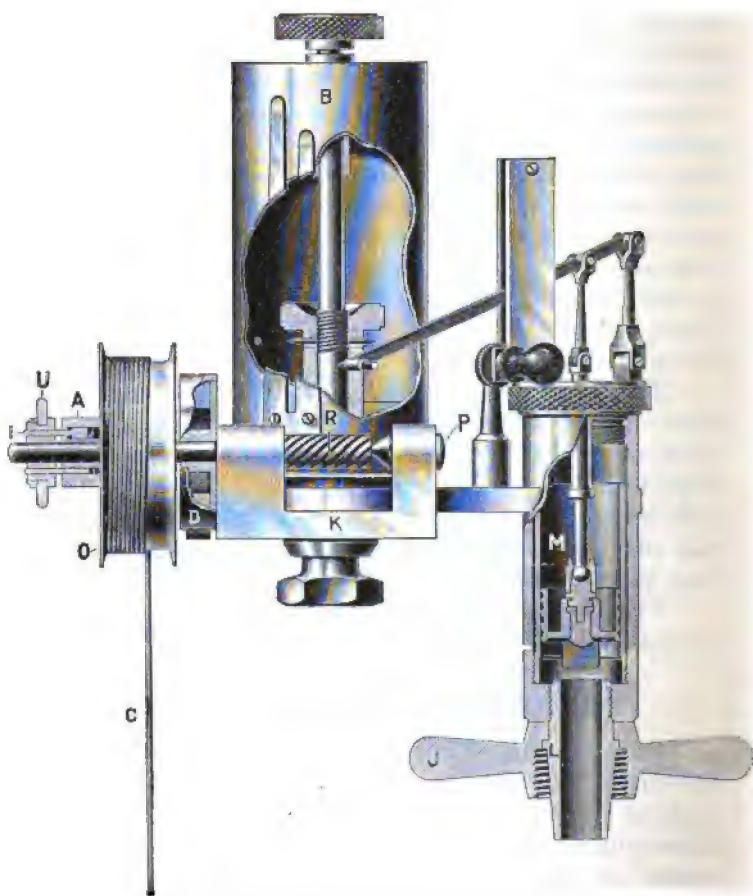
cator, its drum spring being a short spiral having no friction, has a quick recoil, and is scientifically proportioned to the work it has to do. At the beginning of the forward stroke, it offers to the cord only a very slight resistance, which gradually increases by compression, until at the end its maximum is reached. At the beginning of the stroke in the other direction, its strength and recoil are greatest at the moment when both are most needed, and gradually decrease until the minimum is reached at the end of the stroke. Thus by a most ingenious balancing of opposing forces, a nearly uniform stress on the cord is maintained throughout each revolution of the engine.

The drum, 24, and its appurtenances, except the drum spring, are similar in design and function to like parts of other indicators, and need not be particularly described. All the moving parts are designed to secure sufficient strength with the utmost lightness, by which the effect of inertia and momentum is reduced to the least possible amount.

The Crosby indicator is made with a drum one and one-half inches in diameter.

THE CROSBY REDUCING WHEEL.

Construction.—The Crosby reducing wheel, as shown in Fig. 281, is attached directly to the cylinder cock of the steam engine, and has connected to it the steam engine indicator which it is to serve; thus it forms a base or support for the latter, and receives all the strains and shocks in the operations of the engine, to the relief of the indicator. It has a hellical spring which is more active in its purpose than the volute spring in common use, this being a very essential feature for accurate results on high-speed engines. The cord pulley is hori-



The Tabor Steam Engine Indicator, with Houghtaling Reducing Motion.

Fig. 282.

zontal, to allow the cord leading to the engine cross-head to take any direction the circumstances may require, without regard to the position of the indicator.

Whenever the reducing wheel is to be attached to a vertical engine, an elbow nipple is provided which will allow the cord pulley to travel in the proper plane for guiding it to the cross-head of the engine, with the indicator in an upright position as usual.

Operation.—Attach it directly to the cylinder cock of the steam engine by means of the union 4 of the standard 1. Connect the indicator to the standard 1 with the paper drum standing over the spring tube 14, and the indicator guide pulley in a proper position over the stroke pulley 20.

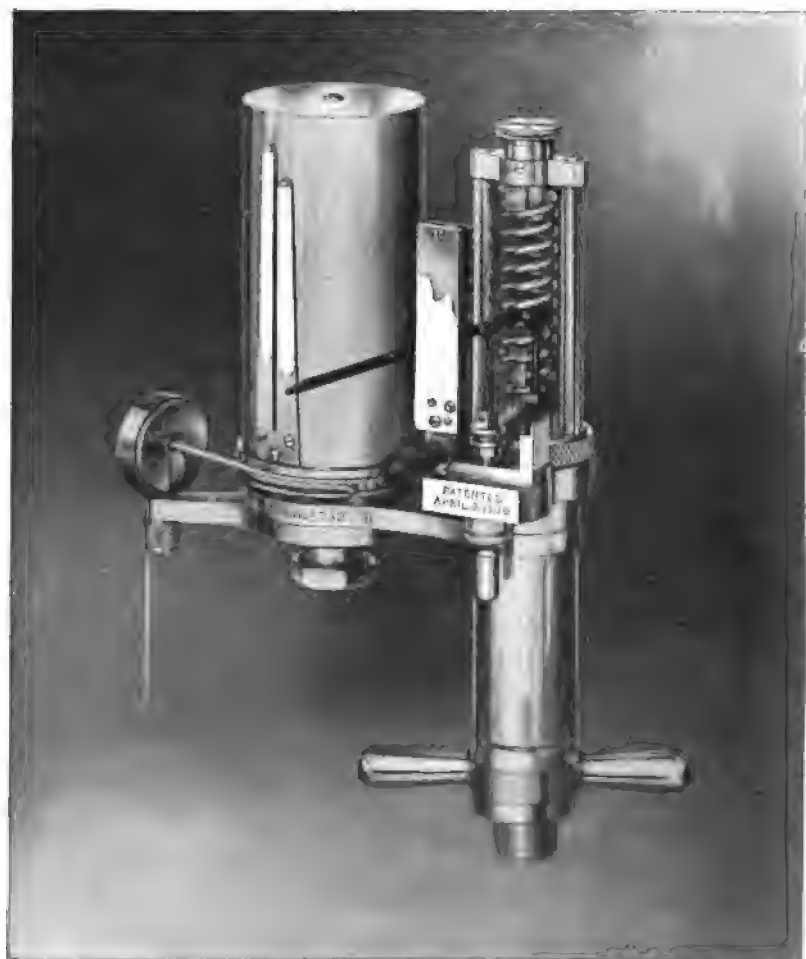
To Attach the Cord Guide.—Loosen the cord guide 24 by means of the screw beneath the cord pulley and move it around to the proper position for the cord to pass directly through the hole in the cord guide without rubbing, to the cross-head of the engine; then tighten it in place.

To Take Up the Tension Spring.—Release the thumb screw 27 in the end of the shaft within the spring tube 14; withdraw the knurled spring head 16 from its square end, and turn it one or more squares as may be desired.

To Adjust the Stroke Pulley.—Remove the knurled disc 21 holding the stroke pulleys 20 in place on the gear shaft; place thereon the stroke pulley desired; replace the disc, and screw it up firmly with the fingers.

To Attach the Indicator Cord.—Adjust the indicator cord one or more turns around the stroke pulley 20, passing the end through the hole in and around the hook of the knurled disc 21.

When Used With Other Indicators.—Loosen the



The Tabor Indicator with Outside Spring.
Fig. 283.

bolt 3 in the side of the standard I where it is attached to the cylinder cock of the steam engine; remove the bushing and insert another fitted to the indicator to be used.

Important Suggestions.—In all cases the indicator cord should be of the right length to prevent the paper drum from recoiling against its stop; and before attaching it to the cross-head of the engine it should be drawn out its full length to ascertain whether or not the cords on the indicator and reducing wheel have been properly adjusted.

All the working parts must be kept well oiled.

The reducing wheel is adapted to be used with a steam engine indicator having either a $1\frac{1}{2}$ -inch or a 2-inch drum. As indicators with 2-inch drums are ordinarily used, the reducing wheel will be provided only with stroke pulleys for such size drum. If the reducing wheel is to be used with an indicator having the $1\frac{1}{2}$ -inch drum, it should be so stated in order to receive the stroke pulleys of the proper size.

TABOR STEAM ENGINE INDICATORS WITH HOUGHTALING REDUCING MOTION.

Construction.—This patent reducing motion, as shown in Fig. 282, composed of a supporting base piece, K, provided with short standards that form bearings for the worm shaft, R, on which the flange pulley, O, is rotated, the outer bearing being a pivot, P, which receives the entire thrust of the shaft, R, thus reducing the friction to a minimum. It is connected direct to the indicator upon the projecting arm that supports the paper drum, B, and the teeth of the worm shaft, R, mesh directly into the teeth on the drum carriage. Connected with the base piece, K, is a spring Case, D, and on the

extreme end of the worm shaft, R, is secured a clutch consisting of a collar, A, through which the clutch pin, I, fastened to the flange holding swivel collar, U, slides freely.

The **flanged pulley**, O, runs freely and independently on worm shaft, R, and has on its outside a clutch-shaped hub. To this pulley, O, is connected the actuating cord, which should encircle it a sufficient number of times to have its length, when unwound, a little more than equal the length of the stroke of the engine. The other end of the cord is secured either to the cross-head of the engine, to a standard bolted thereto, or to any moving part that has an exact similar motion and must be connected in line from the pulley, O.

Enclosed in the **spring case**, D, is a small, plain spiral steel spring which operates solely to return the pulley, O, back to its starting point, after it has been revolved in one direction by the forward movement of the engine cross-head. As this pulley, O, has an independent, rotating back-and-forth motion on the worm shaft R, the necessity of unhooking the cord when the indicator is not being operated is entirely overcome. The paper drum, B, is rotated forward by means of the pulley, O, through its worm shaft, R, engaging with the worm gear, on the paper drum carriage, and in the opposite direction, or backward, by the action of its own retracting spring. On top of paper drum, B, is a knurled thumb piece made with a projecting pin on its under side to engage with a similar pin located in the top of the drum, and is to be used by the operator for moving the paper drum slightly forward preparatory to taking a diagram, to prevent the drum from striking against its stop on the return motion.

With the indicator is furnished for use on the reducing motion, three different sized pulleys, which are of

one-inch, two-inch and three and one-half inches diameters. These pulleys are sufficient for use in taking diagrams from engines having length strokes from six inches to four feet.

Operation.—To operate this device, first select a pulley whose diameter is about one-twelfth of the length of the engine stroke in inches. See table following.

Table of the sizes of pulleys required for use on above style indicator, for piston strokes of various lengths.

Length of Stroke.	Diameter of Pulley.	Length of Stroke.	Diameter of Pulley.
1 Foot	1 Inch	4 Feet	4 Inches
1½ Feet	1½ Inches	4½ "	4½ "
2 "	2 "	5 "	5 "
2½ "	2½ "	5½ "	5½ "
3 "	3 "	6 "	6 "
3½ "	3½ "		

To properly place this pulley upon the worm shaft R, first remove the clutch, and then slide the pulley on to the shaft, being particular that the small hole in the pulley brass disc sets over the projecting pin in the cover of the spring case D. Then replace the clutch by pushing it on to the shaft as far as it will go, and secure it there by means of the set screw.

Next, place the indicator on the engine in such a position that the side of the pulley will be parallel with the motion of the cross-head. Run out the loose end of the cord to a distance of at least 12 or 18 inches, **beyond the extreme forward travel** of the cross-head, still leaving a turn or two of the cord on the pulley unwound. While holding the cord, allow it to gradually recede and rewind itself on the pulley until its loose end has reached a point coincident with the extreme backward travel of

the cross-head. If only a slight tension of the cord exists at this point it will be sufficient, and the cord may then be attached to the selected point on the cross-head. The cord tension may always be adjusted either by winding the cord on, or unwinding it from the pulley, as the case requires, one increasing and the other decreasing the tension.

A much lighter cord can be used in proportion as the sizes of the pulleys increase.

When the **cross-head**, with cord connected, is at its extreme forward travel, there should be just sufficient tension on the spring enclosed in the spring case D to take up all slackness of the cord when running, without overtaxing the spring. If upon starting the engine, the cord should at first run unevenly on the pulley O, turn the indicator to one side slightly, until a perfect and uniform winding of the cord is obtained, which can always be easily secured. When pulley O is running, motion to the paper drum B is obtained by pushing in the swivel collar U, to which the clutch pin is secured.

When ready to take diagrams, after placing the paper on the drum B, it is necessary first to advance the drum away from its stop fully one-quarter inch, which can be done by turning with one hand the knurled top thumb piece. While holding drum in this position, with the other hand push in gently the swivel collar U to start the paper drum in motion. The motion of the paper drum B can, at any time, be stopped, for removing diagrams taken, and renewing the paper, by withdrawing swivel collar U, or by turning top thumb piece, the latter method being preferable. The stopping of the paper drum will not affect the motion of the pulley O, which will continue to revolve independently while the engine is in motion until the cord is disconnected.

Outside Connected Springs.—High temperatures in engine cylinders have had an effect upon indicator construction. The effect of high temperature in both steam and gas engines upon the pressure springs placed inside the cylinders is very injurious and causes rapid deterioration of the springs and consequent inaccuracy of the indicator diagram. To overcome this objection **outside** connected springs are used.

The Tabor Outside Spring.—It will be seen in the illustration shown in Fig. 283 that the only important change to meet these more exacting conditions was the removal of the pressure spring from the inside of the cylinder and placing it on the outside of the indicator where the temperature is but very little higher than the normal temperature of the surrounding atmosphere. This construction is advantageous for several reasons aside from relieving the spring from the deteriorating effect of high temperatures. One particular advantage is that its location outside of the cylinder makes the spring more accessible for changing. To remove or change a spring it is unnecessary to disconnect the indicator or to handle highly heated parts. The spring can be changed immediately if it is desired, and it is never necessary to allow the indicator to cool in order to accomplish this.

Springs for inside and outside spring indicators differ. In ordering, it must be unmistakably stated which style of spring is required.

CHAPTER XXIX.

MECHANICAL REFRIGERATION.

Definition.—Refrigeration is the act of cooling or reducing the temperature of a body, and mechanical refrigeration is reducing of the temperature of a body by artificial means.

Methods.—This cooling process, or refrigeration, can be secured in several ways, viz.: (1) By transferring the heat of a warmer body to a colder one; the warmer body giving up its heat, and hence is cooled. Heat can only be removed from the body by bringing it in contact with a body colder than itself. (2) By the melting and dissolving of solids, thereby **absorbing** the heat from the surrounding bodies. (3) By the **evaporation** of those liquids which have a low boiling point; the latent heat given off by the rapid evaporation representing the degree of cold so produced. (4) By **compression and expansion**; the gas in resuming its original condition necessarily absorbs heat, and thus produces the refrigerating effect. This last action is based upon the well known physical law that when a gas is **compressed**, it gives out heat as its volume is **reduced**. When the gas is allowed to **expand** it **absorbs** the heat from the surrounding bodies, thus reducing their temperature, i. e., it makes them colder. In order to accomplish this refrigerating effect, the substance must have such a **low boiling point** that upon exposure to the atmosphere **rapid evaporation** takes place.

There are several substances that have a sufficiently low boiling point to be employed in the production of artificial cold, such as carbonic acid, ether, nitrous oxide, methalymene and ammonia, but the **expense** of their

production, with the single exception of ammonia, is too great to permit of their use for **practical** work.

The single exception to the above substances, is liquid ammonia, or anhydrous ammonia as it is known.

Anhydrous Ammonia.—This is an alkali liquid, non-inflammable and non-explosive, which boils at a temperature of $28\frac{1}{2}$ degrees Fahrenheit below zero.

When we consider that the freezing point of substances in most general use is 32 degrees Fahrenheit, such substances at freezing temperature would be very warm when compared to the ordinary temperature of this liquid.

The terms **heat** and **cold** are merely **relative** terms. A temperature of 32 degrees Fahrenheit is considered for some purposes extremely cold, and yet when compared to a temperature of 461 degrees below zero, which is the absolute zero of cold so far as yet produced, it then becomes such a high temperature that it could be called a high temperature or **warm** instead of cold.

When two bodies are brought into contact, the warmer of the two always imparts its heat to the other until both bodies have the **same** temperature. That is, the colder body absorbs the heat of the surrounding air and bodies, the same as a sponge absorbs a liquid in which it is immersed.

As the heat from the surrounding bodies is absorbed by the refrigerating bodies, they become colder and the first body becomes warmer until the temperature is equalized.

It is thus seen that the colder body extracts the heat from the other body, and in turn it becomes warmer as the other grows colder.

This is what takes place when ammonia is brought in contact with any substance, and it is by the **evapora-**

tion of ammonia that nearly all artificial ice is now made, as well as all refrigerating.

The ammonia when it is exposed to the atmosphere will evaporate and continue to absorb heat until the substance which is being cooled loses so much of its heat that it becomes as cold as the ammonia. When this point is reached, the ammonia will cease to evaporate, and will remain in a liquid state.

Pressure and Temperature.—If a gas be compressed, its volume will be reduced and its temperature raised by the heat that is squeezed out of it.

When the gas which has been compressed is released it flashes into vapor, extracting heat from the surrounding bodies and thereby lowering their temperature as its temperature rises.

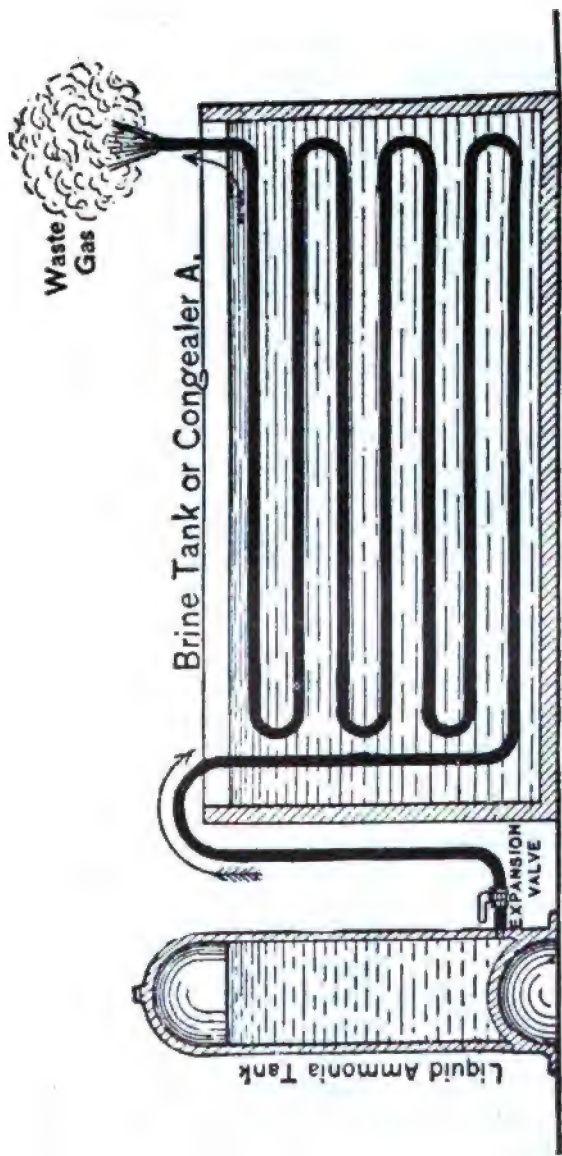
Hence, if a gas while subjected to a uniform pressure be discharged into an air-tight vessel which is being constantly cooled by water, or other substance at a lower temperature than the confined gas, the vapor or gas will condense inside the vessel and return to the liquid form, while the temperature of the cooling water is raised from the heat which it has absorbed from the gas.

The temperature of the cooling water determines the pressure to which the gas must be subjected in order to raise its point of evaporation sufficiently high to enable it to exist as a liquid, when chilled by the surface of the vessel.

All mechanical refrigeration is based upon the above principles.

Refrigerating Apparatus.—The simplest form of a refrigerating apparatus is shown in Fig. 284.

The rapid evaporation of the ammonia which is made to pass through a coil placed in a tank containing water or brine, reduces the temperature of the coil be-



Simplest Form of Refrigerating Apparatus.

Fig. 284.

low the freezing point, and it thereupon absorbs the heat from the surrounding water or brine in the tank or congealer as it is called, until the temperature is reduced below freezing, when it congeals and forms ice, if the tank contains water; or reduces the temperature of the brine below freezing point.

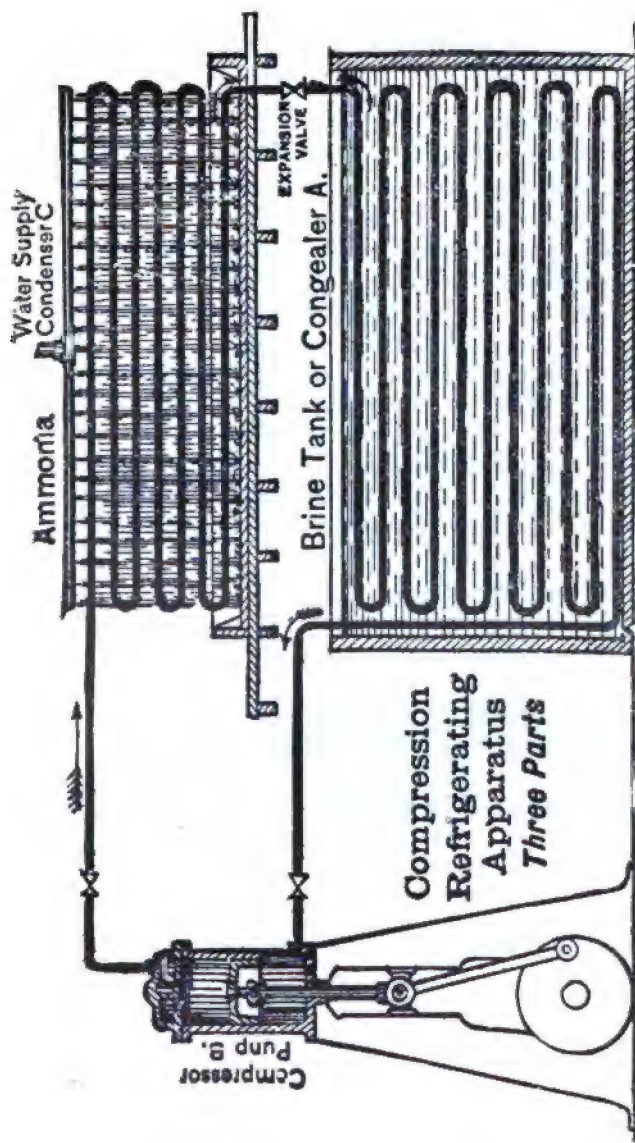
While the work performed by this apparatus is most effective, it is far **too expensive** for practical use, as the ammonia gas is all wasted, it being discharged from the end of the coil as shown in the illustration.

In Fig. 285 is shown a **complete** refrigerating apparatus, in which apparatus the ammonia gas is saved and used over and over again.

By following the direction of the arrows, it will be seen that the ammonia makes a **complete circuit** in its travel. The **actual** work of refrigeration is done by the rapid evaporation of the ammonia in the evaporation coils shown in the congealer or brine tank. The gas is then liquefied for further use by the compressor forcing it through the condenser coil under a pressure of about 175 pounds to the square inch, the heat being absorbed by cold water which flows over the condenser, as shown in the cut.

The **evaporation** coil performs the same duty as the tubes or flues in a boiler. The **steaming** capacity of a boiler depends to a large extent upon the amount of heating surface in the tubes or flues; while the **freezing** capacity of the ice machine depends to a large extent upon the amount of surface of this coil exposed to the air or other substance to be cooled. In a practical apparatus there are a number of such coils used.

The heat absorbed from the surrounding air, or the substance in contact with these coils, causes sufficient heat to be imparted to the ammonia liquid to boil it into



A Simple Compression Refrigerating Apparatus.
Fig. 285.

a vapor, the same as steam is generated by the heat imparted to the water from the fire in the furnace.

As the gas forms in the evaporating coils, the compressor pump is set in motion to suck or draw the gas from the coils as fast as it is formed, drawing it out of the evaporating coils and forcing it into the **condenser**; where the heat which the gas absorbed in its expansion is removed from it by the cooling water which flows over the condenser, leaving the liquid ammonia ready to again be drawn into the expansion coils for further refrigerating work. This operation is a continuous one, it only being necessary to replace at intervals the small amount of ammonia that is lost from leakage. In Fig. 287 is shown the ordinary type of compressor used for this purpose.

Cycle of Operation.—A complete cycle of operation therefore comprises three parts:

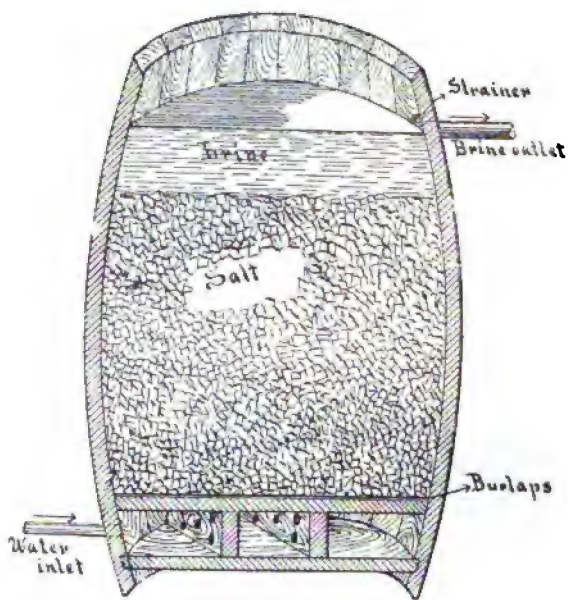
A Compression Side, in which the gas is compressed by the compressor.

A Condensing Side, which consists of coils of pipe in which the compressed gas circulates, **parts** with its heat, and liquefies.

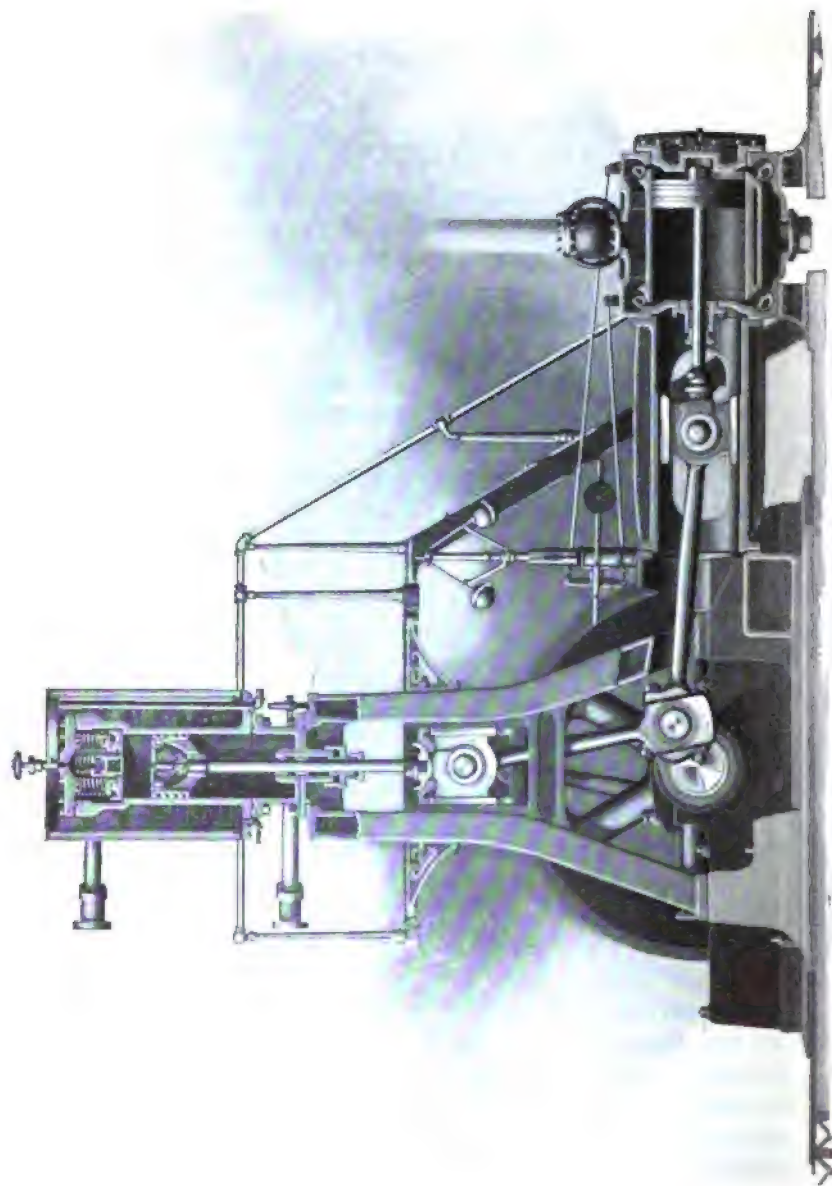
An Expansion Side, which consists of coils of pipe in which the liquefied gas **re-expands** into a gas, **absorbs heat**, and performs the actual refrigerating work.

As we have seen, these three sides or parts are connected together, the gas passing through them in the order named.

The liquefied gas is allowed to flow into the expansion or evaporizing coils, where it is vaporized and expands under a pressure varying from 10 to 30 pounds above that of the atmosphere. The gas then passes into the compressor, is compressed and forced into the condenser, where a pressure of 125 to 175 pounds per square



A Brine Cask.
Fig. 286.



Refrigerating Machine with Vertical Compressor.
FIG. 287.

inch usually exists, thereby producing liquefaction. The resulting liquefied gas is then allowed to flow through a stop-cock having a minute opening, called an expansion valve, which separates the compression from the expansion side of the plant.

The suction or low pressure side of the refrigerating apparatus is connected to the compressor so as to permit of this gas being drawn off as it enters the expansion coil, in this way the pressure being kept at from 10 to 30 pounds above the atmosphere.

From the description of the above apparatus it is apparent that if the expansion coils are placed in an insulated room, that the temperature of the room will be reduced or refrigerated; also if brine or wort is brought in contact with the surface of the coils they also will be reduced in temperature; and that brine so cooled can be used to refrigerate an insulated room by simply forcing it to circulate through pipes or gutters suspended in the same.

The apparatus above described can be used not only for the refrigeration of breweries, packing houses, etc., but also for the manufacture of ice, as will be hereafter explained.

Systems of Refrigeration.—To utilize the cold produced as above shown there are two systems, each of which has its advantages, viz.: (1) By pumping the cold brine, cooled as above explained, through a system of pipes to the apartment to be cooled, which method is called the **brine system**; and (2), By placing the evaporation coils directly in the apartment to be cooled, which system is called the **direct expansion system**.

Brine System.—In this system, the evaporation coils are placed in a tank which is filled with a strong brine usually made of common salt, it being selected as it will

not freeze or coagulate except at temperatures much below zero.

This chilled brine, or non-freezing liquid, is circulated by means of a pump through coils of pipe which are placed on the ceiling, walls, or other convenient places in the apartment to be refrigerated.

This process of refrigeration is therefore just the reverse of heating by steam or hot water pipes; the heat being **absorbed** in the first instance, and **expelled** or **imparted** in the latter.

The brine after absorbing the heat of the apartment, is finally returned to the brine tank, where it is again cooled by the ammonia coils, and is again circulated throughout the cooling, or circulating pipes as they are called.

This operation of refrigeration is therefore a continuous one.

Brine Plant.—A brine plant consists of (1) Compressor, (2) Condenser, (3) Brine Tank, (4) Brine Pump, (5) Ammonia Expansion Coils, and (6) Circulating Pipes.

The advantages of this system over that of the direct expansion system, are, (1) The use of less ammonia, (2) Compactness of machinery, thus permitting all parts of same to be installed in the engine room, where they can be under the constant care of the engineer, (3) Convenience in circulating the brine which has been cooled during the day, at night. As the circulation of the cooled brine requires only the operation of the circulating pump, the fireman or watchman can look after same, thus saving the expense of an engineer.

Preparation of the Brine.—The solution of brine should not be made **stronger** than is necessary to prevent it from freezing. Should the brine be made too strong,

it will impart but little heat between certain temperatures, thereby impeding the cooling or refrigeration. It will also cause a deposit of salt in the circulating pipes, causing them to clog, etc., and also producing a loss of heat-conducting efficiency.

Brine should never therefore contain more than 25 per cent of salt, this being as much as will be held in solution at zero degrees Fahrenheit.

Salometer.—The strength of the brine can be readily ascertained by means of a **salometer**, which is simply an instrument made to float in the brine; the line to which it sinks indicates the percentage of salt, a reference table being used for this purpose.

Brine Cask.—In Fig. 286 is given a common form of a brine cask, which consists simply of a barrel with a false bottom, or wooden grate, about 6 or 8 inches from the bottom, which grating is made of small strips of wood about 1 inch square, and placed not over $\frac{1}{2}$ inch apart. This grating should be supported by two strips of board 6 or 7 inches wide, placed on end and nailed to the bottom. These boards should have several holes bored near the bottom to permit a free passage of the water. The water inlet must be below the false bottom, using $1\frac{1}{4}$ inch pipe. A single thickness of burlap should be stretched over the bottom and tacked to the sides of the barrel. The outlet pipe should be about $1\frac{1}{2}$ inch pipe, and should be located about 5 inches below the top of the barrel. Fill the barrel with salt, and turn on the water. As the salt dissolves readily it is not necessary to stir same. Skim off all waste matter, and provide the outlet with a strainer of some kind to prevent chips, etc., from getting into the brine.

Calcium Brine.—The advantage of using **calcium brine** is its **cleanliness**. It does not clog the pipes, and

in consequence a better conduction of heat is obtained.

Its freezing point can also be depressed several degrees **lower** than when the common salt brine is used.

The objection to its use is solely due to its comparatively **high** price.

It is prepared in a similar manner to the ordinary salt brine.

Pipes in Brine Tank.—For general refrigeration $1\frac{1}{4}$ inch pipe is used; about 150 running feet of this size pipe being allowed for each ton of refrigerating capacity during 24 hours in the brine tank.

In ice making, about 300 feet of this size pipe is used in the brine tank per ton of ice to be manufactured during the 24 hours.

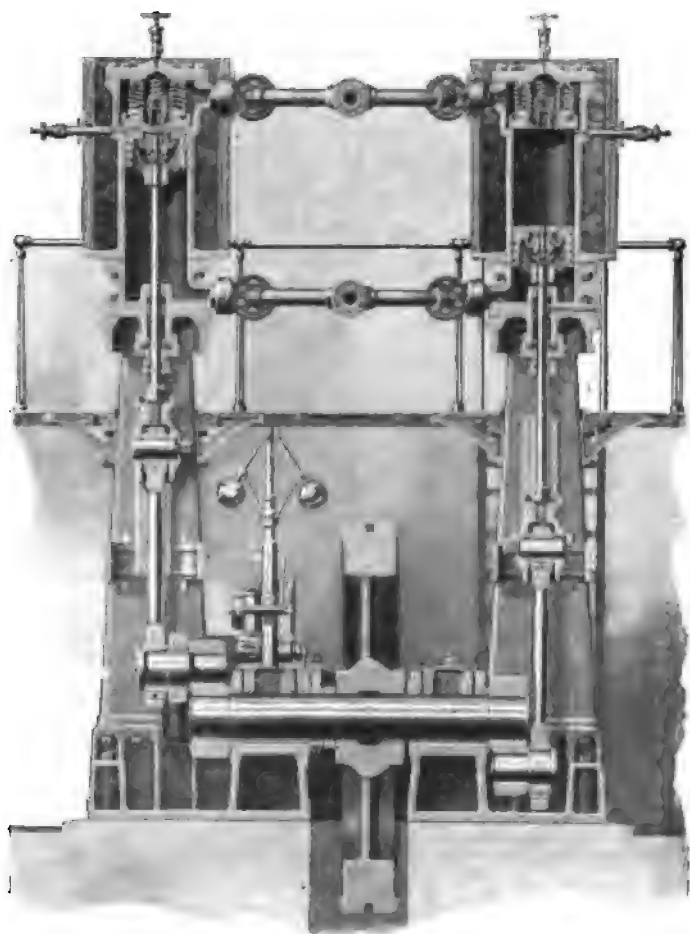
Direct Expansion System.—In this system the expansion or evaporating coils are placed directly in the apartment to be cooled, thereby entirely disposing with the use of a brine in any form.

Advantages.—The apparatus to circulate the brine, together with the power necessary to operate it, is thus saved. A **higher** efficiency is also obtained, as the difference in pressure between the delivery and return side of the compressor is much less than with the brine system.

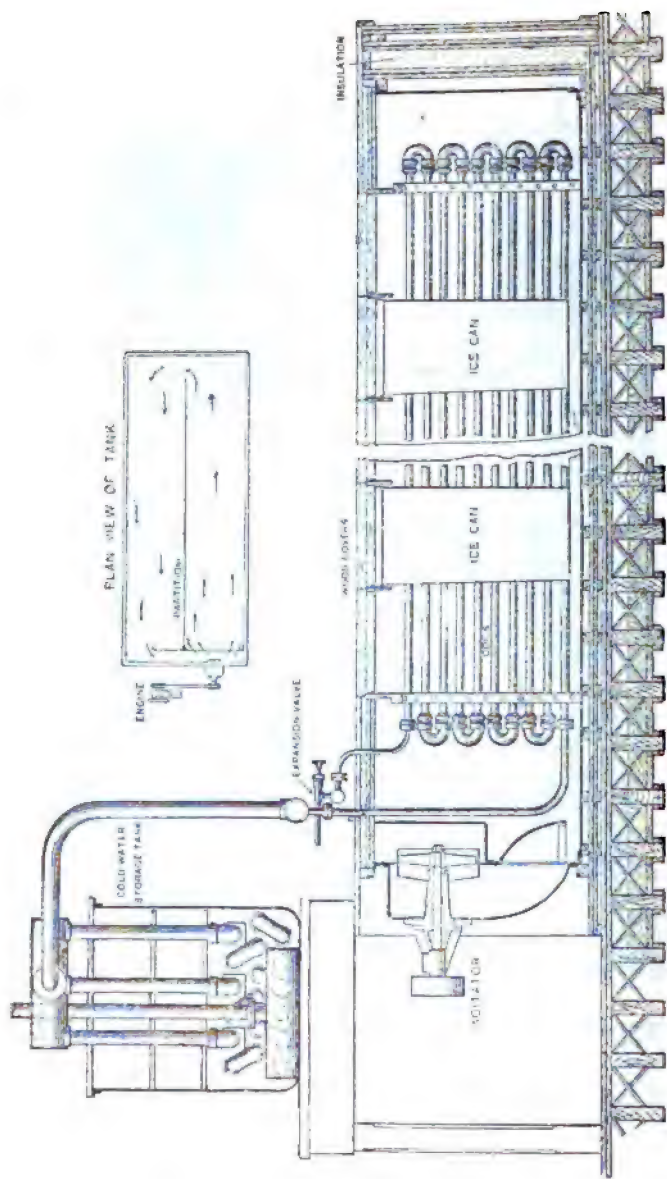
The expense of the first cost is not only much less, but the apparatus itself is much simpler in operation.

Disadvantages.—The disadvantage in the use of this system is the **leakage** in the pipes, as the gas must not only be kept under pressure, but it is extremely penetrating, and attacks the metals ordinarily used.

In order to prevent such leakage, it is necessary that all pipe and fittings be most carefully made and tested to a high pressure. All ammonia fittings are usually made



Cross Sectional View of York Refrigeration Machine.
Fig. 288.



Sectional View of Freezing Tank in Can System.
Fig. 289.

of malleable iron, drop forgings, semi-steel or air furnace iron.

Ammonia has no chemical effect upon iron, and therefore all tanks, pipes or fittings made of iron, may be kept in constant contact with ammonia, and no injurious action will be apparent. The only protection therefore that ammonia expanding pipes require when made of iron, is from corrosion on the **outer** surface of the pipe.

Essential Parts.—A direct expansion system therefore only requires (1) Compressor, (2) Condensor, and (3) Complete system of piping.

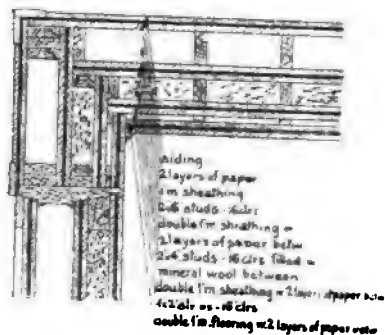
Figs. 287 and 288 show a York refrigerating machine.

Pipe.—The size of pipe usually adopted for expansion coils, when this system is used, is 2-inch pipe, such pipe being lap-welded instead of butt-welded as in the smaller sizes. The **friction** of the gas passing through such pipe, is also much less than when the smaller size is used.

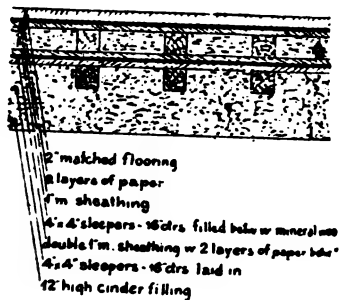
Ice-Making Plant.—There are two principal systems used in the manufacture of ice, viz.: (1) **The can system**, and (2) **The plate system**. In addition to these two systems there is also what is known as the **stationary cell system**, but as this system is rarely used, it will not be considered.

The Can System.—In Fig. 289 is shown a sectional view of the freezing tank used in this system. This tank is filled with salt brine, which is reduced to a temperature of below the freezing point by parallel rows of ammonia evaporating pipes immersed in same. Between these rows of evaporating pipes, sufficient space is left for cans to be inserted.

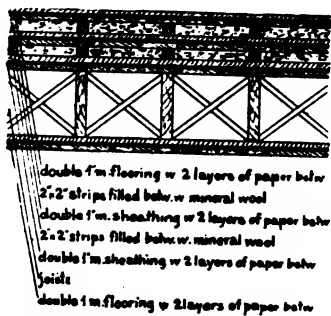
These cans are filled with distilled water, the process of freezing being the same as explained where the brine



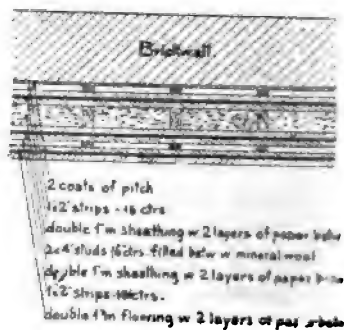
Insulation of walls built of wood



Insulation of ground floor.



Insulation of ceilings for wood construction.



Wooden insulation for brick wall.

Methods of Insulating Buildings.
Fig. 290.

system is used. The ammonia evaporating coils absorb the heat from the brine, and this in turn absorbs the heat from the water in the cans which is to be frozen.

This is the system most in use for the artificial making of ice.

The freezing tank is usually made of iron or wood. The cans are made of galvanized iron, which are covered with wooden tops. The time required to freeze the water in the cans varies from 22 to 48 hours, depending upon the thickness of the mould and the temperature. These ice moulds are generally made 100, 200, 300 and 400 pounds in size; a suitable hoisting apparatus being provided to remove the cans from the tanks. A thawing device is required to loosen the cakes of ice from the cans. Such a device usually consists of a form of a sprinkler, warm water being used. A hot well is often used in which the can is immersed. The cake will then easily slip out of the can, and is ready for the market.

The can is then again re-filled with fresh water, and replaced in its position in the tank, where the freezing again begins. Thus a continuous process is established, which permits of a regular output throughout the day and night. In order to get the greatest production at the least cost, ice-making plants are run day and night.

Plate System.—In this system a hollow plate, usually made of boiler iron, is immersed in a tank containing the fresh water to be frozen.

This hollow plate is filled with brine, which is kept below the freezing point by evaporating coils placed in same, as is done in the can system.

By thus keeping the plate at a sufficiently low temperature, ice will be formed on both sides of it, and in the course of time two layers of ice will be built up on the two sides of the plate. In order to remove this ice,

the cold brine is drawn from the plate, and in case the evaporating coils are inside of the plates, the circulation of ammonia in them is stopped. Tepid water is then supplied to the hollow plates, and after a short while the ice is loosened from them, and can be hoisted out of the tank by means of cranes.

In this system the ice is produced in large pieces, weighing one or more tons, and a length of time of 10 or 12 days is required to freeze it.

This system is used almost exclusively for making ice for skating rinks. The ice is made only once in a season, but the surface which is cut up by the skates is reformed every night. To prevent undue growth and thickness, the ice, from time to time is planed down by a special machine.

Efficiency of Refrigerating Machines.—The useful effect of a refrigerating machine depends upon the ratio between the heat units eliminated and the work expended in compressing and expanding.

The performance of the machine, expressed in pounds or tons of "ice-melting capacity," does not mean that the refrigerating machine would make the same amount of actual ice, but it means only that the cold produced is equivalent to the effect of the melting of ice at 32 degrees, to water of the same temperature.

Therefore, refrigerating machines are rated by the effect they produce equivalent to the melting of a corresponding amount of ice.

The melting of one pound of ice is equivalent to the absorbing of 142 units of heat, but in making ice from water, we have to remove more than the 142 heat units. It is first necessary to reduce the water to 32 degrees before we are ready to produce the ice. If the water is at 70 degrees this means the removal of 30 heat units. But

ice cannot be made with economy without going to a temperature **much lower** than 32 degrees. The ice when formed may have a temperature of 18 degrees, and the specific heat of ice being .5, this means the removal of 7 more heat units; we therefore have to remove 187 heat units instead of 142 units, to produce a ton of ice. Thus a 200-ton machine which would easily produce a refrigerating effect equal to the melting of 200 tons of ice, would produce only **148 tons** of actual ice, when the inevitable losses attending the use of large freezing tanks and the handling of ice is also considered.

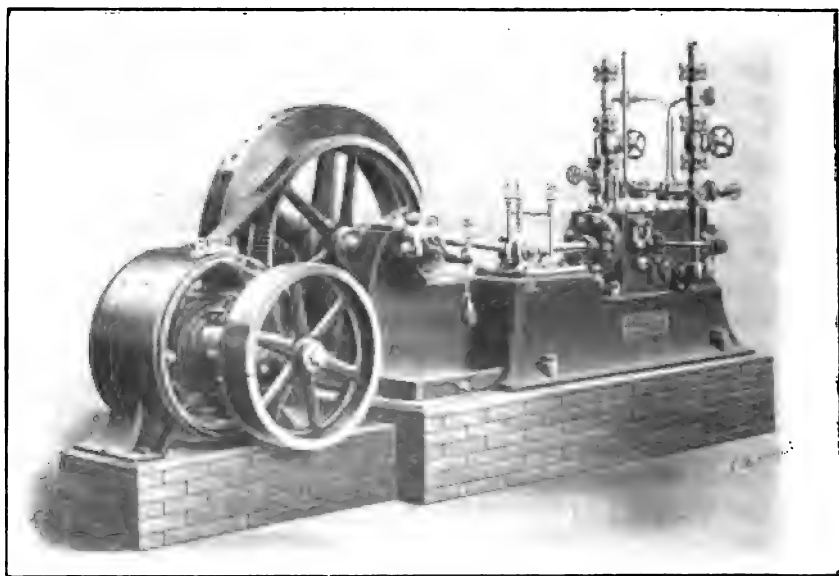
Insulation.—Not only must the pipes running from the compressor to the condenser, and from the condenser to the expansion coils be most carefully insulated, but also the storage rooms.

By proper insulation, the heat **outside** the rooms and pipes, is prevented from penetrating or coming in contact with same, and imposing thereby additional work of refrigeration.

Were it possible to keep the **outside** heat altogether from entering the storage room, it would then be necessary to cool or refrigerate a room **but once**. But this is impossible, and it therefore becomes necessary to construct these cooling or storage rooms with the most **perfect** insulation possible, in order to avoid the employment of a large surplus of refrigerating power to take care of this negative heat.

Since a large percentage of the actual work of the refrigerating plant is required to make up for the passage of heat through the walls, floors and ceilings caused by poor insulation, therefore only **best** insulation should be used.

In Fig. 290 is shown the usual methods of insulating buildings or storage apartments.



A De La Vergne Horizontal Refrigerating Machine.

Fig. 291.

The De La Vergne Horizontal Ice Machine.—This well known type of ice machine is shown in Fig 291, it being their horizontal motor-driven machine of 5, 10 and 15-ton type.

Description.—As in their vertical compressors, the suction and discharge lines are divided and so arranged that they do not have to be disconnected in order to remove the valves. The by-pass valves, used when various parts of the system are to be pumped out; expansion valve for controlling cylinder temperatures while the unit is being put in operation; and the main suction and discharge valves are all conveniently located just above the compressor cylinder within easy reach of the engineer.

The arrangement of the valves peculiar to this machine allows the same port to be utilized for **both** suction and discharge gases. This design not only reduces the effective clearance, but by tempering the extremes of cylinder wall temperatures eliminates to a great extent the disadvantageous effects due to expansion and contraction.

While these compressors are fitted with water jackets for dry compression work, the peculiar method of discharging through ports in the bottom of the cylinder allows this machine to easily discharge large quantities of liquid which might accidentally enter the compressor, without endangering the machine and at the same time making it absolutely impossible for parts of broken valves to get into the cylinder. Two suction and two discharge valves only are used, a point which greatly facilitates the detecting and locating of leaks, and their arrangement at right angles to the cylinder makes their removal as easy as that of a Corliss engine valve.

The De La Vergne System.—In Fig. 292 is shown

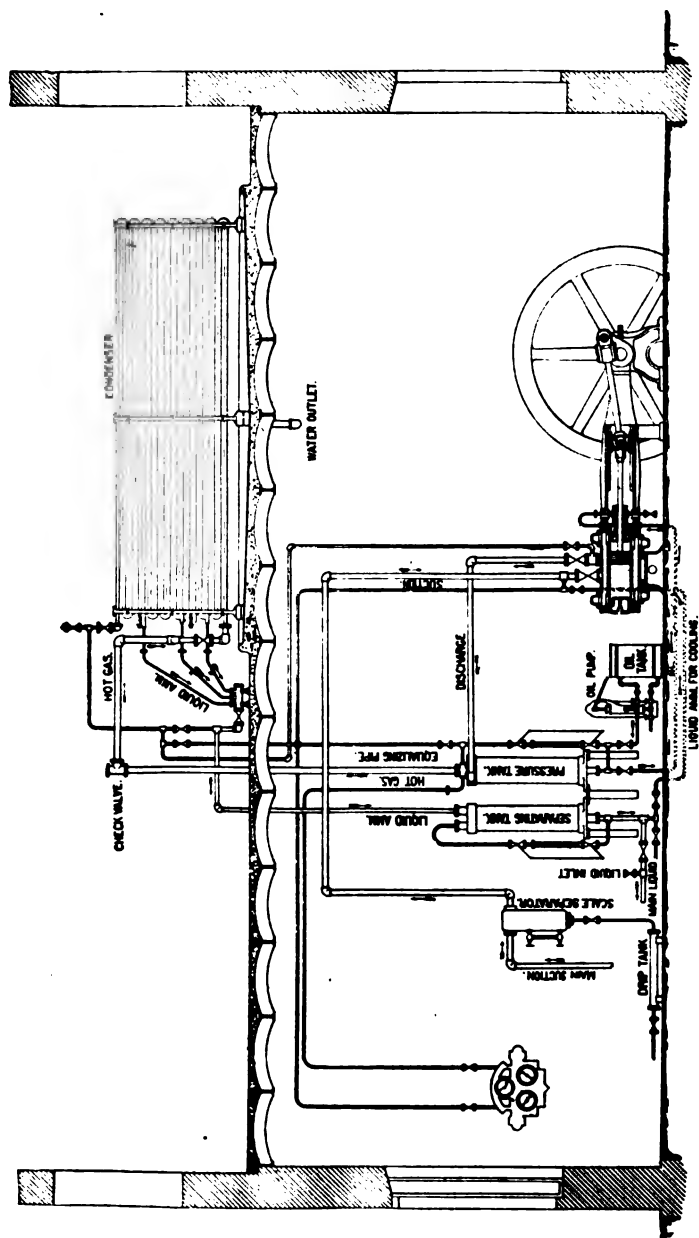
a diagrammatic general arrangement of a typical De La Vergne Refrigerating System. The hot gas discharged by the compressor passes first through a globe valve known as the **discharge valve**, at the left hand side of the cylinder and then to the **pressure tank**. Leaving the pressure tank it passes up the riser marked **hot gas line**, through a **check valve** and down a header through 2-inch pipes and soft seated globe valves of the same size, to the individual stands of atmospheric **condensers**. Leaving the condenser through the three liquid drips, the liquid ammonia from each stand passes down through a half-inch soft metal seated valve into the liquid header.

Before passing to the liquid tank, the outlet from the liquid header rises a few inches to form a **gooseneck**, which maintains a liquid seal on the condenser and prevents gas from the pressure tank from passing into the liquid line, which leads to the expansion coils. Near the part where it connects with the liquid tank, the liquid line from the condenser is provided with a pocket into which any scale or foreign matter is precipitated.

The liquid ammonia leaves the liquid tank at the bottom through the **main liquid line**, a branch from which after passing through a strainer is connected with the main suction line just above the compressor cylinder, and supplies liquid for regulating compressor temperatures while starting up, pumping out, etc.

Just outside the **main liquid valve** a small connection is made into the **main liquid line** to which ammonia drums may be connected for charging the system. Beyond this connection the main line passes to the cold storage rooms and branches out to the individual expansion valves on the various expansion coils.

The ammonia gas returning from each coil passes through a 2-inch soft metal seated globe valve, which



A Complete Refrigerating System.
Fig. 292.

together with the expansion valve allows the individual coils to be pumped out, shut off and disconnected.

The main suction line is provided with a scale separator which prevents any scales or other foreign substances from entering and damaging the compressor and valves.

New oil is introduced into the compressor lubricating system by means of a small pump shown on the side of the main frame casting of the compressor. The oil from this pump is forced through a three-way cock, through the piston rod stuffing box lantern and into the oil pot situated just above the stuffing box. The second line leading from the three-way cock connects with the pressure tank, and through this line the oil carried over with the ammonia gas may be blown back through a strainer into the lubricating system.

By the system of by-passes between the main suction and discharge pipes, the compressor can be reversed so as to pump the ammonia out of any part or the whole of the high pressure side and discharge it into the low pressure side.

Through the cross connection between the main suction and equalizer lines, any one stand of the condenser can be pumped out singly.

Both the liquid and pressure tank are provided with gauge glasses so that the height of the oil or liquid ammonia can be accurately determined at any time.

The condensers are provided with a purging and equalizing header running the entire length of the battery of condensers connected with each stand through a half-inch soft metal seated valve. The impure gases collecting in the top of the condensers may be purged from the header through the **blow-off valve**.

Any ammonia gas entering the oil pot from the stuff-

from the oil blown back from the back pressure tank passes up through the **equalizer to oil pot** and enters the main suction from the top. A continuation of this line furnishes the low pressure gauge connection, while the high pressure gauge is connected to the pressure tank.

CHAPTER XXX.

HOISTING AND PORTABLE MACHINES.

Description.—The handling and moving of large quantities of heavy and bulky material has become a separate and distinct branch of engineering.

The small vertical, or donkey engine as it is usually called, with attached hoisting apparatus, has made possible the immense steel buildings that are daily being erected in our cities, while the excavating and conveying machinery has enabled us to build canals and the great subways which are taking the place of the elevated railways in the larger cities.

The **steam shovel** has built our railroads, and upon them rests the future of the great Isthmian Canal.

Almost all our coal is mined by the hoisting engine, in fact, the hoisting engine has been the greatest agent in modern developments.

Extent of Work Done.—The extent of the great work done by this class of machinery, and the exceedingly low cost of same, can be seen from the following instances:

In excavating the Chicago Canal, a 60-ton steam shovel handled 600 cubic yards of hard cement gravel in a day of ten hours, while the 70-ton machines excavated about 700 cubic yards each.

The contract price paid for handling this material varied from 20 to 50 cents per cubic yard.

A 70-ton steam shovel with $2\frac{1}{2}$ yard dipper, has handled ore in the Michigan field at 2.53 cents per ton.

One hundred-ton steam shovels are now numerous, and with them the cost of handling material has been reduced even below that of the above figures.

To operate these steam shovels, and similar portable and hoisting machines, three engines are generally used; the main engine which operates the hoisting and propelling machinery, a smaller engine used for swinging the boom and dipper, and a third engine for thrusting the dipper handle.

The size of a steam shovel is usually denoted by the capacity of the dipper in cubic yards and the weight of the whole machine in tons.

The following are some of the standard sizes:

Weight, tons.....	35	45	55	65	75	90
Dipper, cu. yds.....	1¼	1½	1¾	2	2½	3
Coal in 10 hrs., tons	¾	1	1¼	1½	2	2¼
Water in 10 hrs.gals.	1,500	2,000	2,500	3,000	4,000	4,500

The price of shovels is approximately \$130 per ton.

The Hoisting Engineer.—It is therefore seen that the hoisting engineer must operate and have under his constant supervision the following throttles and levers: One swinging throttle, one hoisting throttle, one reverse lever, and one friction lever.

He must not only be a **skilled** engineer, quick and alert, but also a most **careful** and **reliable** man, for the lives of many workmen would be endangered by any carelessness on his part.

SIGNALS ADOPTED BY HOISTING AND PORTABLE ENGINEERS.

Boom derrick with one bell or whistle.

One blow or ring, stop.

Two blows or rings, hoist the load.

Three blows or rings, lower the load.

Four blows or rings, hoist the boom.

Five blows or rings, lower the boom.

With two bells, one on load and one on boom.

Bell on Load.

One ring, stop.

Two rings, hoist.

Three rings, lower.

Bell on Boom.

One ring, stop boom.

Two rings, raise boom.

Three rings, lower boom.

Brick Hoist.

One ring, stop.

Two rings, hoist.

Three rings, load to lower.

Four rings, man coming down.

BOOM-DERRICK SIGNALS.

(1) To Raise the Load.—Arm bent at elbow and hand twisted or shaken from wrist. Speed depends upon the speed with which the hand is moved.

(2) **To Raise the Boom.**—Arm bent at elbow, hand closed and thumb extending upward, the hand being moved up and down. The speed depends upon the speed with which the hand is moved.

(3) **To Stop.**—The extended arm moved horizontally from the shoulder, with the open hand.

(4) **To Lower the Boom.**—Arm extended with hand about level with waist, and a downward motion made with the hand closed, with thumb extending downward.

(5) **To Lower the Load.**—Arm extended with hand about level with waist, and a downward motion made with open hand from wrist.

(6) **To Raise Boom and Load.**—The same signals are given as in (1) and (2); one signal being given with each hand.

(7) **To Raise the Boom and Lower the Load.**—The signals are given with each hand, as in (2) and (5).

(8) **To Stop.**—Signal to stop is given by a horizontal movement of the arm.

When this movement is made with the arm with which signals are given for operating boom, it means to **stop the boom**. The same movement with the arm with which signals are given for operating the load, mean **stop or hold the load**.

RUNNER SIGNALS FOR LINE FROM NIGGER-HEAD.

(1) **To Take in Line or Go Ahead.**—Arm extended with hand about level with hips; the open hand being shaken or twisted from the wrist.

(2) **To Stop.**—Arm is moved horizontally, with the hand open.

(3) **To Slack Off.**—Arm extended, and a downward twisting motion made with hand from wrist; the hand being about on a level with the waist.

POTTER MACHINE.

The signal-man stands on the carriage facing the engineer when he is ready to signal to hoist the bucket, and he gives the signal by extending his arm slightly below the level of his shoulder. As the bucket is being hoisted, he raises his arm higher as a signal to go faster; and when the bucket is clear of obstructions, he raises his arm still higher and by shaking his hand from the wrist he signals to go still faster, the engineer continuing to hoist the bucket until he sees that it is landed in the carriage. The signal-man then releases the trigger that holds the bucket in place.

The signal-man faces the direction the carriage is going to travel, and signals to go ahead by swinging his arm horizontally; when the signal-man wishes to go **slow**, he holds his arm out from the shoulder, and to continue to go slow, is signaled by a slow horizontal movement of the arm. A signal to **stop** is given by dropping his arm to his side.

The signal-man then dumps the load.

Facing the engineer, he signals to bring the carriage back in the same manner that he signaled to go ahead. When the carriage has been brought to a stop over the ditch, the signal-man releases the trigger that holds the bucket, and signals to **lower** the bucket by holding his arm straight out. When he wishes to let the bucket

down **faster**, he raises his arm **higher**; when he wishes to lower slowly, he drops his arm a little; when he wishes to **drop** the bucket, he signals to do so by extending his arm from the shoulder with his hand raised, and by moving his hand **up and down**, the engineer lets it drop **rapidly**, so there will be enough slack to change the hook from one bucket to another.

TYPE OF STEAM SHOVEL.

Steam Shovel.—In Fig. 295 is shown the ordinary type of a steam shovel at work.

SPECIFICATIONS FOR A 55-TON STEAM SHOVEL.

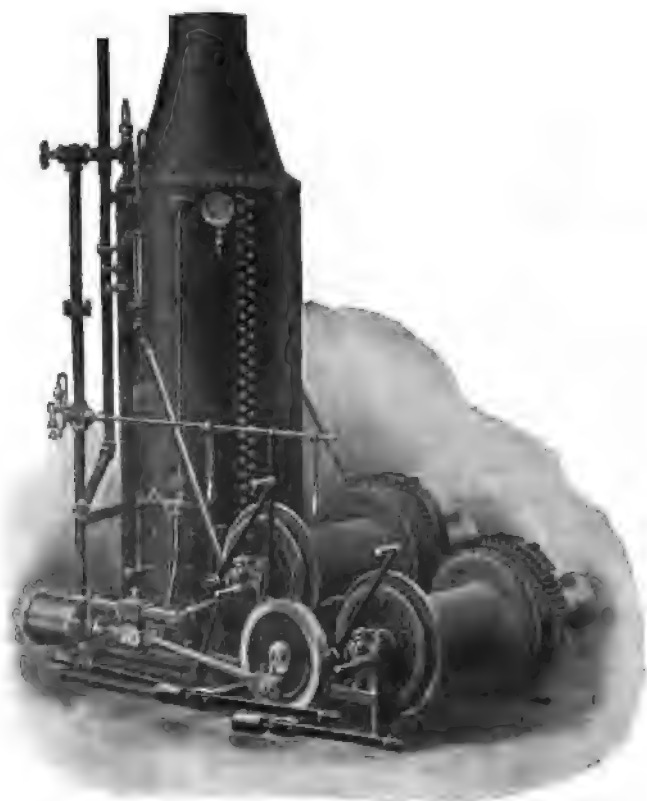
Boiler, fire box type, 54"x12' 3".
Hoisting engine, double, 10"x12".
Craning engine, double, 6"x6".
Radius, 26' 0".
Clear lift, 13' 0".
Boom guys, 2½" diameter.
Boom, 24' 11¼".
Back leg, 2"x4".
Hoisting chain, 1⅛".
Dipper capacity, 2 cubic yards.
Dipper handle, 16' 6".
Length of machine, 35' 5¼".
Height from track, 13' 2¼".
Height to top of trucks, 3' 7⅛".
Distance between center of trucks, 24' 1¾".
Capacity of water tank, 1,000 gallons.
Diameter of drum, 18".

TENSILE STRENGTH OF DIFFERENT KINDS OF WIRE ROPE, COMPARED WITH MANILA ROPE

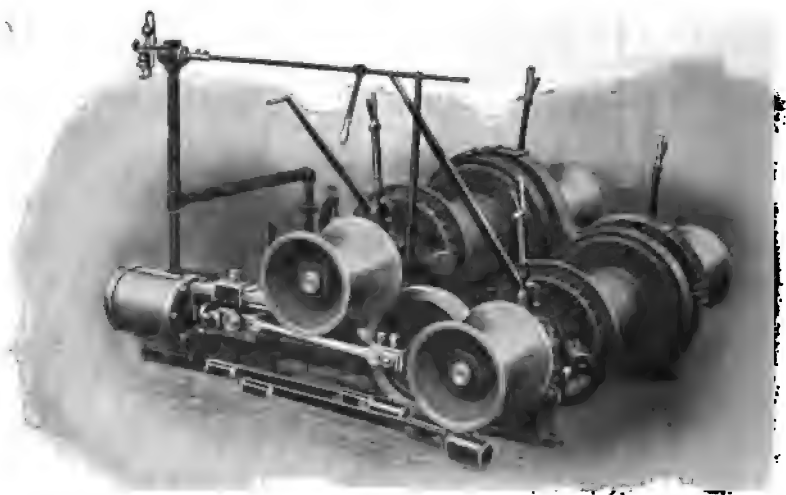
APPROXIMATE BREAKING STRESS CALCULATED IN TONS OF
2,000 POUNDS

Diameter in Inches.	Wire Transmission Rope. One hemp core surrounded by six strands seven wires each.				Wire Hoisting Rope. One hemp core surrounded by six strands of nineteen wires each.				Average Quality New Manila Rope.
	Iron.	Crucible Cast Steel.	Extra Strong Crucible Cast Steel.	Plow Steel.	Iron.	Crucible Cast Steel.	Extra Strong Crucible Cast Steel.	Plow Steel.	
23/4	....	....	....	....	114	228	266	305	26
21/2	....	....	....	....	95	190	222	254	21
21/4	....	....	....	....	78	154	182	208	17
2	....	....	....	....	62	124	144	165	13 1/2
13/4	....	....	....	....	48	96	112	128	11
15/8	....	....	....	....	42	84	97	111	9 1/2
11/2	34	68	79	91	36	72	84	96	8
13/8	29	58	68	78	31	62	72	82	7
11/4	24	48	56	64	25	50	58	67	6
11/8	20	40	46	53	21	42	49	56	5
1	16	32	37	42	17	34	39	44	4
7/8	12	24	28	32	13	26	30	34	3
3/4	9.3	18.6	21	24	9.7	19.4	22	25	2 1/4
5/8	6.6	13.2	15.1	17	6.8	13.6	15.8	18	1 3/4
1/2	5.3	10.6	12.3	14	5.5	11.0	12.7	14.5	1 1/4
1/2	4.2	8.4	9.70	11	4.4	8.8	10.1	11.4	1
3/8	3.3	6.6	7.50	8.55	3.4	6.8	7.8	8.85	3/4
3/8	2.4	4.8	5.58	6.35	2.5	5.0	5.78	6.55	1 1/8
1/8	1.7	3.4	3.88	4.35	1.7	3.4	4.05	4.50	3/8
1/8	1.4	2.8	3.22	3.65	....	....	....	....	1/8
....	....	....	....	....	1.2	2.4	2.70	3.00	1/8

The American Steel and Wire Co.
Table No. 27-(1).



A Lambert Hoisting Engine.
Fig. 293.



A Double Cylinder Friction Drum Hoisting Engine.
Fig. 294.

Hoisting Engine.—In Fig. 293 is shown a Lambert hoisting engine, especially adapted for building erection, and extensively used by bridge builders and structural iron workers. The engine in this cut has two independent friction drums fitted with ratchets and pawls which are used for ordinary hoisting in the usual manner. It also has four winch heads, two fixed on the drum shafts and two independent winch heads, which are loose on the outward shaft, operated by an improved spiral jaw clutch, which is thrown in and out of gear by means of upright lever, as shown in the cut. These levers are provided with thumb latches and work on notch quadrants to prevent the clutch from accidentally becoming disengaged. These winches are provided with ratchets and pawls for holding the load suspended while the other winches and drums are being operated.

The whole machine is designed for heavy duty. The shafts are of steel of large diameter. The winches are large and the proper shape to do the work in a satisfactory manner. Foot brakes can be attached to both drums when specially ordered.

TABLE OF SIZES AND DIMENSIONS OF HOISTING ENGINES.

Horse Power Usually Rated.	DIMENSIONS OF CYLINDERS.		DIMENSIONS OF DRUMS.		Weight Hoisted, Single Line.	DIMENSIONS OF BOILER.	
	Diam. Inches.	Stroke, Inches.	Diam. Inches.	Length Between Flanges Inches.		Diam. Shell, Inches.	Height Shell, Inches.
14	6½	8	14	22	3500	34	84
18	6¾	10	14	24	4500	36	84
25	7½	10	14	28	7000	40	90
60	10½	14	16	34	14000	52	106

Double Cylinder Double Friction Drum Hoisting Engine.—In Fig. 294 is shown a type of this engine espe-



A Steam Shovel.

Fig. 295.

cially adapted for bridge building, structural iron work and erection of all classes. This engine has four improved independent clutch winches.

TABLE OF SIZES OF HOISTING MACHINES.

Horse Power Usually Rated	DIMENSIONS OF CYLINDERS		DIMENSIONS OF DRUMS.		Weight Hoisted. Single Line. Usual Speed.
	Diam. Inches.	Stroke Inches.	Diam. Inches.	Length Between Flanges.	
20	7	10	14	18	5000
30	8½	10	14	24	8000
40	8½	12	16	29	10000
60	10½	14	16	32	15000

PROPER SPECIFICATIONS FOR THE CONSTRUCTION OF PARTS OF HOISTING ENGINE MACHINES.

Friction Drums.—Long experience has proven that no form of friction drum is equal in durability, simplicity and sensitive action to one where contact is maintained by the pressure of a screw and prompt and sensitive release is maintained by a releasing spring between the drum head and the friction head. The capacity of such a drum has been completely established by thousands of such drums in use for the past twenty years. All attempts to secure success and leave out the recoil spring have been failures, and the attempts to overcome this deficiency by a double bevel or V contact, finally resulted in the return to the recoil spring. It is all a question of correct angle of the conical contact surface and the diameter of the friction head. A single faced conical bearing will hold and release better than a double V shaped face

when the angle between the bevel face and straight face is the same as that between the two bevel faces of the double V, and to make the double V release with equal sensitiveness, it has to be blunter, while the unequal expansion caused by the heat generated by friction will act to enlarge the diameter of the metal surface, while the wooden contact surface remains the same, so that the double V surface, ultimately, in action, becomes a single gearing surface, while the single bevel surface automatically accommodates itself to changes of temperature.

The operation of the pressure screw on the drum is such that no end thrust is imparted to the drum shaft, nor to the back stand to spread the two stands.

Gearing.—Cast iron spur gears are used on account of their more lasting chilled surfaces, made from accurately cut patterns, while all the pinions are heavily shrouded and made of a high grade of cast steel.

Winch Heads.—The winch heads are of extra diameter and length, the same size and shape at each end, with a parallel surface in the middle. This design will be readily appreciated by those who have used a wet line on the common type of winch head, particularly when slacking off. The bearings on this side of the engine are double the length and the winch head comes close against the bearing, thus avoiding springing the shafts, as is frequently the case with the older designed engines.

Foot Brakes.—All engines are made so that foot brakes can be put on at any time if they are found necessary, but are only sent with engines when especially ordered. They are only recommended for long, heavy hoists, or when desired to use the engine for other purposes while the weight hangs suspended. The regular

friction drum is all that is required for ordinary hoisting and lowering purposes.

Fly Wheels.—Fly wheels used on single cylinder engines are of cast iron with face turned crowning and ample width of belt face to transmit full power of engine when used for pumping, sawing or other purposes.

Guard Bands.—Guard bands are used to cover the gearing so as to protect the rope or prevent any other accident from obstructions getting into the teeth.

Cylinder Drain Cocks.—Cylinder drain cocks are provided for every cylinder and at both ends. They are all connected to a single lever convenient for the engineer, and are available in lowering heavy loads against back steam pressure.

Size	Standard Pitch, Dist. from cen. of one link to cen. of next.	Average weight per foot in lbs.	Outside Length Inches	Outside Width Inches	DREDGE, HOISTING AND SHOVEL CHAINS		
					Proof Test in lbs.	Approximate breaking strain in lbs.	Average safe working load in lbs.
3/4	1 1/2	1 1/4	1 1/4	3/4	2,500	5,000	1,666
1	2	1 1/2	1 1/2	1 1/4	3,500	7,000	2,340
1 1/4	2 1/2	1 3/4	1 3/4	1 1/2	5,000	10,000	3,335
1 1/2	3	2	2 1/4	1 3/4	7,000	14,000	4,670
1 3/4	3 1/2	2 1/4	2 3/4	1 7/8	9,000	18,000	6,000
2	4	2 3/4	3	2	11,000	22,000	7,335
2 1/4	4 1/2	3	3 1/4	2 1/8	14,000	27,000	9,335
2 1/2	5	3 1/4	3 1/2	2 1/4	17,000	34,000	11,335
2 3/4	5 1/2	3 3/4	3 3/4	2 1/2	20,000	40,000	13,335
3	6	3 3/4	3 3/4	2 1/2	23,000	46,000	15,335
3 1/4	6 1/2	4	4	2 3/4	26,000	52,000	17,335
3 1/2	7	4 1/4	4 1/4	3	29,000	58,000	19,335
3 3/4	7 1/2	4 1/2	4 1/2	3 1/4	32,000	64,000	21,335
4	8	4 3/4	4 3/4	3 1/2	35,000	70,000	23,335
4 1/4	8 1/2	5	5 1/4	3 3/4	40,000	80,000	26,665
4 1/2	9	5 1/4	5 1/4	3 3/4	46,000	92,000	30,665
4 3/4	9 1/2	5 1/2	5 1/2	4	51,000	102,000	34,000
5	10	5 3/4	5 3/4	4 1/4	54,000	108,000	36,000
5 1/4	10 1/2	6	6 1/4	4 1/2	58,000	116,000	38,665
5 1/2	11	6 1/4	6 1/4	4 3/4	62,000	124,000	41,335
5 3/4	11 1/2	6 1/2	6 1/2	5	67,000	134,000	44,665
6	12	6 3/4	6 3/4	5 1/4	70,500	141,000	47,000
6 1/4	12 1/2	7	7 1/4	5 1/2	77,000	154,000	51,335
6 1/2	13	7 1/4	7 1/4	5 3/4	79,000	158,000	52,665
6 3/4	13 1/2	7 1/2	7 1/2	5 3/4	83,000	166,000	55,335
7	14	7 3/4	7 3/4	6	89,000	178,000	59,335
7 1/4	14 1/2	8	8 1/4	6 1/4	95,000	190,000	63,335
7 1/2	15	8 1/4	8 1/4	6 1/2	101,000	202,000	67,335
7 3/4	15 1/2	8 1/2	8 1/2	6 3/4	108,000	216,000	72,000
8	16	8 3/4	8 3/4	6 3/4	115,000	230,000	76,665
8 1/4	16 1/2	9	9 1/4	7	122,000	244,000	81,335
8 1/2	17	9 1/4	9 1/4	7 1/4	129,000	258,000	86,000
8 3/4	17 1/2	9 1/2	9 1/2	7 1/2	136,500	273,000	91,000
9	18	9 3/4	9 3/4	7 3/4	152,000	304,000	101,335
9 1/4	18 1/2	10	10 1/4	8	168,500	337,000	112,335
9 1/2	19	10 1/4	10 1/4	8 1/4	181,000	362,000	120,665
9 3/4	19 1/2	10 1/2	10 1/2	8 1/2	193,500	387,000	129,000
10	20	10 3/4	10 3/4	9	206,000	412,000	137,335
10 1/4	20 1/2	11	11 1/4	9 1/4	218,000	436,000	145,335

Pitch, Dimensions, Weights, Breaking Strains, Etc., of
Steam Shovel, Dredge and Hoisting Chains.
Table No. 27-(2).

CHAPTER XXXI.

LAWS AND REGULATIONS PROVIDING FOR THE INSPECTION OF BOILERS AND THE LICENSING OF ENGINEERS AND FIREMEN.

The following laws and regulations have been selected not only on account of the general information contained in them, but also as containing much valuable knowledge of especial interest to the student of steam engineering.

Graded License.—While a graded license for engineers has been adopted by many of the States, owing to the difficulty in enforcing its requirements, it has not met with universal success. The St. Louis license law which provides for only one grade of engineer's license is given as a model law, it being entirely practical and its requirements strictly enforced.

Licensing Firemen.—The licensing of firemen, but placing them under the engineer who is in charge of the plant, is meeting with much favor, and the ordinance of New York City providing for the licensing of firemen is therefore given in full.

UNITED STATES GOVERNMENT REGULA- TIONS.

For the Inspection of Boilers and the Licensing of Engineers.

Inspection of Boilers.—Sec. 4418. The local inspectors shall also inspect the boilers of all steam vessels before the same shall be used, and once at least in every year thereafter. They shall subject all boilers to the hydrostatic pressure; and shall satisfy themselves by thorough examination that the boilers are well made, of good and suitable material; that the openings for the

passage of water and steam, respectively, and all pipes and tubes exposed to heat, are of proper dimensions and free from obstruction; that the spaces between and around the flues are sufficient; that the flues are circular in form; that the fire line of the furnace is at least two inches below the prescribed minimum water line of the boilers; that the arrangement for delivering the feed water is such that the boilers can not be injured thereby; and that such boilers and machinery, and the appurtenances, may be safely employed in the service proposed in the written application, without peril to life. They shall also satisfy themselves that the safety valves are of suitable dimensions, sufficient in number, and well arranged; and that the weights of the safety valves are properly adjusted, so as to allow no greater pressure in the boilers than the amount prescribed by the inspection certificate; that there is a sufficient number of gauge cocks properly inserted, **and suitable steam gauges to indicate the pressure of steam**; and that there are reliable low-water gauges; and that the fusible metals are properly inserted so as to fuse by the heat of the furnace, whenever the water in the boilers falls below its prescribed limits; and that adequate and certain provision is made for an ample supply of water to feed the boilers at all times, whether such vessel is in motion or not, so that in high-pressure boilers the water shall not be less than four inches above the top of the flues; and that means for blowing out are provided, so as to thoroughly remove the mud and sediment from all parts of the boilers, when they are under pressure of steam. All boilers used on steam vessels and constructed of iron or steel plates, inspected under the provisions of section forty-four hundred and thirty, shall be subjected to a hydrostatic test, in the ratio of one hundred and fifty

pounds to the square inch to one hundred pounds to the square inch of the working steam power allowed. No boiler or pipe, nor any of the connections therewith, shall be approved, which is made, in whole or in part, of bad material, or is unsafe in its form, or dangerous from defective workmanship, age, use, or other cause.

Control of Safety Valves.—Sec. 4419. One of the safety valves may, if in the opinion of the local inspectors it is necessary to do so, be taken wholly from the control of all persons engaged in navigating such vessel and secured by the inspectors.

Stamping of Boiler Plates.—Sec. 4431. Every plate of boiler-iron or steel, made for use in the construction of steamboat boilers, shall be distinctly and permanently stamped by the manufacturer thereof, and, if practicable, in such places that the marks shall be left visible when such plates are worked into boilers, with the name of the manufacturer, the place where manufactured, and the number of pounds tensile strain it will bear to the sectional square inch; and the inspectors shall keep a record in their office of the stamps upon all boiler plates and boilers which they inspect.

Pressure of Steam Allowable.—Sec. 4433. The working steam-pressure allowable on boilers constructed of plates inspected as required by this title, when single-riveted, shall not produce a strain to exceed one-sixth of the tensile strength of the iron or steel plates of which such boilers are constructed; but where the longitudinal laps of the cylindrical parts of such boilers are double-riveted, and the rivet holes for such boilers have been fairly drilled instead of punched, an addition of twenty per centum to the working pressure provided for single-riveting may be allowed: Provided, that all other parts of such boilers shall correspond in strength to the addi-

tional allowances so made; and no split-calking shall in any case be permitted.

Rule for Determining Steam Pressure Allowed on Boilers.—Multiply one-sixth (1-6) of the lowest tensile strength found stamped on any plate in the cylindrical shell by the thickness—expressed in inches or parts of an inch—of the thinnest plate in the same cylindrical shell, and divide by the radius or half diameter—also expressed in inches—and the sum will be the pressure allowable per square inch of surface for single riveting, to which add 20 per cent for double riveting, when all the rivet holes in the shell of such boiler have been “fairly drilled” and no part of such hole has been punched.

Pressure Allowed on Bumped Heads.—Multiply the thickness of the plate by one-sixth of the tensile strength, and divide by one-half of the radius to which head is bumped, which will give the pressure per square inch of steam allowed.

Pressure Allowed After Ten Years' Service.—Any boiler having been in use ten years or more shall, at the first annual inspection thereafter, be drilled at points near the water line, and at bottom of shell of boiler, or such other points as the local inspectors may direct, to determine the thickness of such material at those points, and the general condition of such boiler or boilers at the time of such inspection; and the thickness of said material shall be determined thereafter at such annual inspection as the local inspector may deem necessary, and the steam pressure allowed shall be governed by such ascertained thickness and general condition of the boiler.

License of Engineer.—Sec. 4441. Whenever any person applies for authority to perform the duties of engineer of any steam vessel, the inspectors shall ex-

amine the applicant as to his knowledge of steam machinery, and his experience as an engineer, and also the proofs which he produces in support of his claim; and if, upon full consideration, they are satisfied that his character, habits of life, knowledge, and experience in the duties of an engineer are all such as to authorize the belief that he is a suitable and safe person to be intrusted with the powers and duties of such a station, they shall grant him a license, authorizing him to be employed in such duties for the term of five years, in which they shall assign him to the appropriate class of engineers; but such license shall be suspended or revoked upon satisfactory proof of negligence, unskillfulness, intemperance, or the willful violation of any provision of this title. Whenever complaint is made against any engineer holding a license authorizing him to take charge of the boilers and machinery of any steamer, that he has, through negligence or want of skill, permitted the boilers in his charge to burn or otherwise become in bad condition, or that he has not kept his engine and machinery in good working order, it shall be the duty of the inspectors, upon satisfactory proof of such negligence or want of skill, to revoke the license of such engineer and assign him to a lower grade or class of engineers, if they find him fitted therefor.

MASSACHUSETTS LAW.

To Provide for the Licensing of Engineers and Firemen.

Section 1. It shall be unlawful for any person to have charge of or to operate a steam boiler or engine in this Commonwealth, except boilers and engines upon locomotives, motor road vehicles, boilers in private residences, boilers in apartment houses of less than five flats,

boilers under the jurisdiction of the United States, boilers used for agricultural purposes exclusively, boilers of less than eight horse power, and boilers used for heating purposes exclusively which are provided with a device approved by the chief of the district police limiting the pressure carried to fifteen pounds to the square inch, unless he hold a license as hereinafter provided; and it shall be unlawful for any owner or user of any steam boiler or engine, other than those boilers or engines above excepted, to operate or cause to be operated a steam boiler or engine for a period of more than one week, unless the persons in charge and operating such boiler or engine are duly licensed.

Section 3. Any person desiring to act as engineer or fireman shall make application for a license to so act, to the examiner of engineers for the city or town in which he resides or is employed, upon blanks to be furnished by the examiner. The application must show his experience during the preceding three years or time of service. The applicant shall be given a practical examination, and if found competent and trustworthy, he shall receive within six days after the examination, a license graded according to the merits of his examination, irrespective of the grade of license for which he applies. The applicant shall have the privilege of having one person present during his examination, who shall take no part in the same, but who may take notes, if he so desires. No person shall be entitled to receive more than one examination within ninety days, except in the case of an appeal as hereinafter provided. A license shall continue in force for three years, or until the same is revoked for incompetency or untrustworthiness; and a license shall remain revoked until a new license is granted. A license, un-

less so revoked, shall at the end of said three years be renewed by an examiner of engineers upon application and without examination, if the application for renewal is made within six months of expiration of license. In case a new license of different grade is issued, the old license must be destroyed in the presence of the examiner. In case of the loss of a license by fire or other means, a new license shall be issued in its place, without re-examination, upon satisfactory proof of such loss to an examiner.

Section 4. Licenses shall be granted according to the competency of the applicant and shall be distributed in the following classes: Engineer's licenses,—first class, unlimited in horse power. Second class, to have charge of and operate any boiler or boilers and any engine not exceeding one hundred and fifty horse power. Third class, to have charge of and operate any single boiler and any engine not exceeding fifty horse power. Firemen's licenses,—first to operate any boiler or boilers. Second, to have charge of and operate low pressure heating boilers where the pressure carried is less than twenty-five pounds to the square inch. Any person desiring to have charge of or to operate any particular steam plant or type of plant, may be examined as to his competency for such service and no other, and if found competent and trustworthy, shall be granted a license for such service and no other; but no person shall be examined for a special license for a particular plant unless a written request for such examination, signed by the owner or user of said plant, is filed with the application.

Section 5. The words "have charge" in this act shall be construed to designate the person under whose supervision a boiler or engine is operated. The "person oper-

ating" shall be understood to mean any and all persons actually engaged in generating steam in any power boiler.

Section 6. The horse power of any boiler shall be ascertained upon the basis of three horse power for each square foot of grate surface, for a power boiler, and on the basis of one and one-half horse power for each square foot of grate surface if the boiler is used for heating purposes exclusively. The engine power shall be reckoned upon a basis of a mean effective pressure of forty pounds per square inch of piston for a simple engine; fifty pounds for a condensing engine; and seventy pounds for a compound engine, reckoned upon area of high pressure piston.

Section 9. Any person dissatisfied with the action of any examiner in refusing or revoking a license, may appeal from his decision within one month from such decision, to the remaining examiners, who shall together act as a board of appeal, and a majority of whom shall have the power to hear the parties and pass upon the subjects of appeal. The party appealing may have the privilege of having one first-class engineer present during the hearing of his appeal, who shall take no part in the same. The decision of the majority of such remaining examiners so acting shall be final, if approved by the chief of the district police.

AMENDED LAW.

To Provide for the Licensing of Engineers and Firemen.

The amended license law in Massachusetts which takes effect December 1, 1906, reads as follows:

Engineers' Licenses.—First class, to have charge of and operate any steam plant. Second class, to have

charge of and operate a boiler or boilers, and to have charge of and operate engines, no one of which shall exceed 150 horse power, or to operate a first-class plant under the engineer in direct charge of the plant. Third class, to have charge of and operate a boiler or boilers not exceeding in the aggregate 150 horse power, and an engine not exceeding 50 horse power, or to operate a second-class plant under the engineer in direct charge of the plant. Fourth class, to have charge of and operate hoisting and portable engines and boilers.

Firemen's Licenses.—Extra first class, to have charge of and operate any boiler or boilers. First class, to operate any boiler or boilers. Second class, to have charge of and operate any boiler or boilers where the pressure does not exceed 25 pounds to the square inch, or to operate high pressure boilers under the engineer or fireman in direct charge thereof. A person holding an extra first or first-class fireman's license may operate a third-class plant under the engineer in direct charge of the plant. A person holding an engineer's or fireman's license who desires to have charge of or to operate a particular steam plant or type of plant may, providing he holds an engineer's or fireman's license, if he files with his application a written request signed by the owner or user of said plant for such examination, be examined as to his competence for such service and no other, and if found competent and trustworthy shall be granted a license for such service and no other. No special license shall be granted to give any person charge of a plant over 150 horse power.

PENNSYLVANIA LAW.

To Provide for the Licensing of Engineers.

Section 1. Be it enacted, &c., That it shall be un-

lawful for any person or persons to have charge of or to operate a steam boiler or steam engine over ten horse power, in cities of the first-class of this Commonwealth, except locomotive boilers used in transportation, and steam engines and steam boilers carrying less than fifteen pounds pressure per square inch, unless said person or persons are upwards of twenty-one years of age and holds a license, as hereinafter provided for, and it shall be unlawful for any owner or owners, user or users, of any steam boiler or steam engine over ten horse power, other than those excepted above, to operate or cause to be operated a steam boiler or steam engine without a duly licensed engineer.

Section 2. All persons desiring authority to perform the duties of an engineer shall apply to the boiler inspector of such cities, who shall examine the applicant as to his knowledge of steam machinery and his experience in operating the same, also the proofs he produces in support of his claim, and if, upon full consideration, the inspector is satisfied that the applicant's character, habits of life, knowledge, and experience in the duties of an engineer, are all such as to authorize the belief that he is a suitable and safe person to be entrusted with the powers and duties of such a station, he shall grant him a license upon the payment of three (\$3) dollars, authorizing him to be employed in such duties for the term of one year, and such license shall be annually renewed, without examination, upon the payment of one (\$1) dollar, provided it is presented for renewal within ten days after its expiration. Licenses so granted shall be graded into two classes: One of which shall entitle the licensee to have charge of or to operate stationary steam boilers and steam engines only; the other of which shall entitle the licensee to have charge of or to operate

portable steam boilers and steam engines only; such licenses shall not be transferred from one grade to the other without a re-examination, said re-examination to be conducted without cost to the licensee.

No person shall be eligible for examination for a license unless he furnishes proof that he has been employed about a steam boiler or steam engine for a period of not less than two years prior to the date of application, which must be certified to by at least one employer and two licensed engineers.

Section 6. All engineers licensed under the provisions of this law shall assist the inspector in his examination of any boiler under his charge, and shall point out all defects and imperfections known to them in the boilers or machinery, and, in default thereof, the license of any such engineer or engineers, so neglecting or refraining, shall be revoked by the inspector.

Section 8. It shall be the duty of an engineer when he assumes charge of boilers and machinery, to forthwith thoroughly examine the same, and if he finds any part thereof in bad condition, caused by neglect or inattention on the part of his predecessor, he shall immediately report the facts to the inspector, who shall thereupon investigate the matter, and if the former engineer has been culpably derelict of duty, he shall suspend or revoke his license.

Section 9. It shall be the duty of every licensed engineer when he vacates a position as engineer to notify the boiler inspector of such fact, and any failure to comply with this provision shall be punishable by a suspension of the license for such period or periods as the boiler inspector may determine.

CITY OF CHICAGO.**Inspection of Steam Boilers and Other Apparatus Used for the Generation of Steam.**

Section 9. **Duties of the Board.**—It shall be the duty of the Board to inspect all boilers, tanks, jacket kettles, generators or other apparatus used for generating or transmitting steam for power, or using steam under pressure for heating or steaming purposes, and all other tanks, jacket kettles and reservoirs under pressure of whatsoever kind, except as hereinafter provided, as often as once in each and every year, by making a hydrostatic pressure test where such tests shall be deemed necessary; provided, that the hydrostatic pressure used in such test shall not exceed the maximum working pressure of said apparatus by more than fifty per cent; and by making a careful external and internal examination. In all cases where hydrostatic pressure test is used an internal examination of said apparatus shall afterwards be made. In certifying the working pressure allowed on each steam boiler, steam generator or other apparatus the same shall be determined by multiplying one-fifth of the lowest tensile strength of any plate in the cylindrical shell of said steam boiler or steam generator or other apparatus by the lowest efficiency of joint in such cylindrical shell expressed in decimals, and by multiplying the product by the thickness, expressed in inches or parts of an inch, of the thinnest plate in the same cylindrical shell and divide by the radius, also expressed in inches. This sum will be the pressure allowable per square inch of surface.

Any boiler, tank, jacket kettle, generator or reservoir having been in use eight years or more and its condition being such that in the opinion of the inspector

the same should be drilled in order that the exact thickness and condition may be ascertained, he shall report the same to the Chief Inspector of Steam Boilers, who shall serve the owner or agent with a written notice to show cause to the Chief Inspector within five days why such boiler, tank, jacket kettle, generator or reservoir should not be drilled.

If, after the owner or agent has been heard, or at the end of five days, the Chief Inspector deems it necessary that the boiler, tank, jacket kettle, generator or reservoir be drilled, then the boiler, tank, jacket kettle, generator or reservoir may be drilled at points near the water line, and at the bottom of shell of boiler, or such other points in the boiler, tank, jacket kettle, generator or reservoir as the inspecting officer may direct, and the thickness of said material shall be determined thereafter at such annual inspection as the inspecting officer may deem necessary, and the steam pressure or other pressure allowed shall be governed by such ascertained thickness and general condition of boiler, tank, jacket kettle, generator or reservoir. And the drilling and plugging of said holes shall be done at the expense of the owner.

Any boiler may be tested and rated in accordance with the United States Marine Inspection Law governing the inspection of steam boilers. But no boiler, tank, jacket kettle or jacket constructed or re-constructed of boiler plates hereafter, where the same are required, shall have stay bolts of less than seven-eighths of an inch in diameter and pitched more than seven inches apart. And all stationary boilers, tanks, jacket kettles or jackets carrying a pressure of one hundred pounds or over to the square inch, the construction of which requires stay bolts, shall be equipped with hollow stay bolts. All

boiler heads made of boiler plate shall be braced with braces, the sectional area of which shall not be less than one square inch each, so pitched that a greater strain of six thousand pounds per square inch of section shall not be carried by any one brace or stay bold. In computing the strain on braces in flat surfaces the diameter of brace rivets shall be considered. In computing the strain on shells having dished heads the pressure will be figured according to the radius of the heads.

Section 12. Duty of Owners.—It shall be unlawful for any person to use any steam boiler or any tank or tanks subject to pressure other than city pressure, until he shall have first procured a certificate from said Board that said apparatus may be safely used, and that the boiler or boilers, boiler setting, means of producing draft, smoke connections, and furnace or fire-box are of such size and capacity that they will do the work required, and be capable of being so managed for the purpose of generating steam that no dense smoke shall be emitted from the chimney connected with such furnace or fire-box.

If such owner, agent or person using a steam boiler or tank shall fail to notify said Board of his intention to make any alteration, repairs or enlargement of such steam plant, and shall fail to file plans and specifications for the enlargement or alterations of the same, and shall proceed to make such alteration, repairs or enlargement without a permit therefor, he shall be liable to a fine of twenty-five dollars (\$25.00) for each day on which he shall have prosecuted such alteration, repairs or enlargement without said permit, and each day's violation shall constitute a separate offense. Provided, however, that minor necessary or emergency repairs which do not increase the capacity of said apparatus or involve any substantial alteration of structure may be

made by or under the engineer in charge of said apparatus without permit or report thereof.

If at any time when inspecting a steam boiler, generator or other apparatus used for generating steam for power or heating purposes the Inspector of Boilers shall find that the furnace or fire-box in which fuel is used for the purpose of generating steam is so constructed or operated as to cause the emission of dense smoke from the chimney connected therewith he shall report to said Board the condition of said plant. The owner of said steam boiler, generator or apparatus shall have the right to put in such appliance or make such alterations or use such fuel as in his judgment will prevent the emission of dense smoke, but this shall not constitute a compliance with this ordinance unless such appliance or such fuel shall actually prevent the emission of dense smoke.

Provided, boilers on locomotives or tugs, and any steam boiler, generator or other apparatus carrying other than city pressure in flat buildings or apartment buildings shall be subject to inspection as hereinbefore provided.

Provided, also, that any boilers for heating purposes, only, in which the permit specifies that not more than ten pounds of steam pressure to the square inch shall be carried, shall be known as "low pressure boilers."

After the next inspection of such boilers shall have been made following the adoption of this ordinance, inspections thereafter shall be made once in every three years. But all of such low-pressure plants may be inspected at any time thereafter, and without charge, with reference to the provisions for draft, complete combustion or degree of combustion of fuel and prevention of the emission of smoke.

CITY OF NEW YORK.**To Provide for the Licensing of Firemen.**

Section 1. It shall be unlawful for any fireman or firemen to operate steam stationary boiler or boilers in the City of New York, unless the fireman or firemen so operating such boiler or boilers are duly licensed as hereinafter provided. Such fireman or firemen to be under the supervision and direction of a duly licensed engineer or engineers.

Section 2. Should any boiler or boilers be found at any time operated by any person who is not a duly licensed fireman or engineer as provided by this act, the owner or lessee thereof shall be notified, and if after one week from such notification the same boiler or boilers is again found to be operated by a person or persons not duly licensed under this act, it shall be deemed prima facie evidence of a violation of this act.

Section 3. Any person desiring to act as a fireman shall make application for a license to so act, to the steam boiler bureau of the police department as now exists for licensing engineers, who shall furnish to each applicant blank forms of application, which application when filled out shall be signed by a licensed engineer engaged in working as an engineer in the City of New York, who shall therein certify that the applicant is of good character, and has been employed as oiler, coal-passer or general assistant under the instructions of a licensed engineer on a building or buildings in the City of New York, or on any steamboat, steamship or locomotive for a period of not less than two years. The applicant shall be given a practical examination by the board of examiners detailed as such by the police commissioner and if found competent as to his ability to operate a steam

boiler or boilers as specified in section one of this act shall receive within six days after such examination a license as provided by this act. Such license may be revoked or suspended at any time by the police commissioner upon the proof of deficiency. Every license issued under this act shall continue in force for one year from date of issue unless sooner revoked as above provided. Every license issued under this act unless revoked as herein provided shall at the end of one year from date of issue thereof, be renewed by the board of examiners upon application and without further examination. Every application for renewal of license must be made within thirty days of the expiration of such license. With every license granted under this act there shall be issued to every person obtaining such license a certificate, certified by the officers in charge of the boiler inspection bureau. Such certificate shall be placed in the boiler room of the plant operated by the holder of such license, so as to be easily read.

Section 4. No person shall be eligible to procure a license under this act unless the said person be a citizen of the United States.

Section 5. All persons operating boilers in use upon locomotives or in government buildings, and those used for heating purposes carrying a pressure not exceeding ten pounds to the square inch, shall be exempt from the provisions of this act. Such license will not permit any person other than a duly licensed engineer to take charge of any boiler or boilers in the City of New York.

CITY OF PHILADELPHIA.

Inspection of Steam Boilers.

10. The inspector shall, by himself or his assistants personally, at least once in every year, examine each sta-

tionary steam boiler with reference to the following particulars: 1. Thickness and kind of plates employed. 2. Their apparent condition as regards imperfections, wear or injury. 3. All new boilers hereafter made, whenever they are constructed in whole or in part of wrought-iron sheets riveted together, shall have the maker's name and the quality of the material stamped upon each sheet in accordance with the inspection laws of the United States for steamboats.

He shall also inspect the feeding apparatus, together with the various attachments required to be placed on the boilers and their pipe connections.

11. He shall determine the pressure that shall be allowed to be carried on stationary steam boilers when they are made in whole or in part of wrought-iron sheets riveted together, and be governed by the following rules in estimating the maximum pressure at which stationary steam boilers may be worked.

12. In estimating the strength of the longitudinal seams in the cylindrical shells of boilers, he shall apply two formulæ:

Formula A. Pitch of rivets—(Diameter of the holes punched to receive the rivets)÷(Pitch of rivets)=(Percentage of the strength of the sheet at the seam as compared to the strength of the solid part of the same sheet).

Formula B. (Area of hole filled by the rivet)x (number of rows of rivets in the seam)÷(pitch of rivets) x(thickness of the sheet). This product x(shearing strength of the rivet)÷(tensile strength of the sheet)= Percentage of the strength of the rivets in the seam as compared to the strength of the solid part of the sheet.

$$\frac{A}{p} \times \frac{N}{t} \times \frac{S}{T} = \text{Percentage}$$

That the shearing strength of a rivet in a composite joint made of iron rivets and steel plates shall not be considered in excess of forty thousand (40,000) pounds. Take the lowest of the percentages as found by formula (A or B) and apply that percentage as the value of the seam in the following formula (C), which determines the strength of the longitudinal seams.

Formula C. (Thickness of the boiler plate, expressed in parts of an inch) \times (Value of the seam as obtained by Formula A or B) \times (Ultimate strength of the iron in the plates) \div (Internal radius of the boiler in inches) \times (Factor of safety)=(Pressure per square inch at which the safety valve may be set).

14. Boiler flues and furnaces of cylindrical form submitted to external pressure, tending to cause the cylinder to collapse, when formed of wrought-iron plates united by rivets, and all the seams made with lap-joints, shall be rated by the following rule:

"Eighty-nine thousand six hundred (89,600) multiplied by the square of the thickness, and this amount divided by the length, in feet multiplied by the diameter in inches of the flue, equal the safe load."

N. B.—This rule is based on the assumption that the circumferential seams act as braces, and reduce the unsupported length of the flue or furnace to the length of the sections joined by the circumferential seams.

15. The area of stay-bolts and stays submitted to strain shall be measured at their least section, and one-fifth of the breaking strength of the iron shall be assumed as the safe working load, if the ductility test of the iron does not exceed fifteen (15) per cent, but may be taken at one-fourth when the ductility test shows twenty (20) per cent or over. The allowable strain on stay bolts or stays of unknown quality of iron shall never

be considered higher than seven thousand five hundred (7,500) pounds per square inch of section, measured at the point of least section.

16. If the radius of the curvature of the convex head of the boiler be equal to the diameter of the shell of the boiler to which it is attached, then the metal in the head sheet must be of the same thickness as the plates used in the shell or cylindrical part, and no bracing is necessary. All flat heads must be stayed up to the value of the shell when not held by well secured flues or tubes. Domes and manholes in the shell of the boiler must be made as strong as the other parts of the boiler, by any of the well-known methods to the satisfaction of the inspector.

22. Each boiler shall have upon it three gauge cocks and one glass water gauge, or in place of the gauge cocks a second glass water gauge. Each should have an independent connection with the boiler itself. If one connecting pipe is used for both apparatus, it must be at least nine (9) square inches area, and all the connections to which shall be made with not less than one and one-quarter ($1\frac{1}{4}$) inch pipe. Gauge cocks, when used, must be so placed that the middle gauge must be at least four (4) inches above the top of the flues, tubes or crown of the fire box. The lowest point of vision of the water in glass gauge must be above the top of flues, tubes or crown of the fire box.

23. Every boiler, when fired separately, and every set or series of boilers, when placed over one fire, shall have attached thereto, without the interposition of any other valve, two or more safety valves, the aggregate area of which shall have such relations to the area of the grate and the pressure within the boiler as is expressed in schedule A, attached to this ordinance; and

every safety valve shall have an arm or bearer distinctly notched and marked with five pounds or ten pounds divisions, and shall have but one "P" or ball for a weight. The weight of said "P" or ball is to be determined by the inspector, the pounds and ounces of which shall be stamped or plainly marked on the weight and on the lever, and a record of the same is to be kept in the office of the inspector; and the arm shall not have greater length than will allow the "P" to be placed so as to produce on the boiler the maximum pressure which the certificate authorizes to be carried.

Schedule A, Referred to in Section 23.

Least aggregate area of safety valve (being the least sectional area for the discharge of steam) to be placed upon all stationary boilers with natural or chimney draft.

This area may be expressed by the formula

$$A = \frac{22.5 G}{P + 8.62}$$

in which A is area of combined safety valves in inches. G is area of grate in square feet. P is the pressure of steam in pounds per square inch to be carried in the boiler above the atmosphere.

The following table gives the results of the formula for one square foot of grate as applied to boilers used at different pressures:

Pressure Per Square Inch.

10	20	30	40	50	60	70	80	90	100	110	120
1.21	0.79	0.58	0.46	0.38	0.33	0.29	0.25	0.23	0.21		0.17

[Area corresponding to one square foot of grate.]

Example: Boiler 25 square feet of grate area and sixty pounds pressure.

For one square foot (from table) 0.33

25 square feet.

8.33 square inches.

This would call for two safety valves each, with 4.16 square inches area of 2.3-10 diameter.

26. The charges for inspection which shall be paid by the user or users of boilers in use by any single person, firm or company which may be inspected in one inspection, shall be as follows, viz.: For each and every boiler the sum of three (3) dollars, and for each and every square foot of grate surface twenty (20) cents.

CITY OF ST. LOUIS.

Inspection of Boilers and Licensing of Engineers.

Manner of Inspection.—Section 2203. The manner of inspection shall be substantially as follows: The owners of steam boilers and users shall have the option of taking the hammer test or the hydrostatic test; also of electing whether the Inspector of Boilers and Elevators or one of the Assistant Inspectors, mentioned in this chapter and employed and paid by the insurance companies, shall make such test. If the hammer test be asked for, the examination shall be thorough and searching upon every part of the boiler, both internally and externally, including all fittings and attachments. If the hydrostatic test be asked for, each boiler shall be tested by the hydraulic pressure one-fourth greater than the ordinary working steam pressure used, and the certificate of inspection herein provided shall state the maximum pressure at which any boiler may be worked. In case a defect shall be discovered in any boiler or attachment thereto, the Inspector of Boilers and Elevators shall report the same to the owner or user of said boiler or boil-

ers, and state the facts of the case in writing, giving a description of the particular locality in which each defect may be found, and whether of a dangerous character and necessitating immediate repair. If the Inspector of Boilers and Elevators shall at any time find a boiler which, in his judgment, is unsafe, after inspecting same, he shall condemn its further use. All boilers to be tested by the hydrostatic pressure shall be filled with water by the owners or users, and they shall furnish the necessary labor required to work and handle the pumps in applying the test. When leaks occur which prevent a successful test, the Inspector of Boilers and Elevators shall make a second test, upon receiving notice that all leaks have been repaired. If, upon making a second test, the boiler or boilers are still defective, he shall for each subsequent test, collect an additional inspection fee, but in no case shall he give a certificate until fully satisfied of the safety of the boiler or boilers. All certificates of inspection shall be for one year and no longer. Any owner or user of any boiler or boilers insured by any steam boiler inspection and insurance company duly authorized to transact business in the State of Missouri, shall, upon his request, have the hydrostatic test applied once annually, without extra charge, by the assistant boiler inspector of such company, as provided in this chapter.

Plans and Specifications.—Section 2236. Hereafter any manufacturer or builder of boilers, upon receiving a contract to construct a boiler to be installed within the limits of the City of St. Louis, shall notify the Inspector of Boilers and Elevators of the fact, and submit to him plans and specifications of same. All plates or sheets used in the construction of any boiler which is to be installed in any building within the City of St. Louis shall be carefully inspected, as well as the workmanship

of said boiler, by the Inspector of Boilers and Elevators, and the same condemned if not in compliance with the required standard. Hereafter any manufacturer or builder of elevators, upon receiving a contract to erect or construct an elevator within the limits of the City of St. Louis, shall notify the Inspector of Boilers and Elevators of the fact, and file a copy of the plans and specifications of said elevator therewith for his approval, showing the size and construction of the sheaves, drum, ropes or cables, and all automatic devices thereon, together with the clearance at top and bottom of the shaft, and the automatic locking devices on the doors or gates to the shaft. Before said boiler or elevator is put in operation, a certificate shall be obtained as provided for in Section 2234.

License of Engineers.—Section 2205. Said board shall provide for regular sessions, and the Inspector of Boilers and Elevators shall act as secretary and keep minutes of the proceedings. Said board shall convene for business once in each week to examine into the qualifications of applicants for engineers' licenses. A majority of the members of said board shall constitute a quorum for the transaction of business. The secretary shall keep a register of the names of all applicants, designating those found qualified and those not qualified. Said board shall grant certificates of licenses, for one year from date thereof, to all applicants who, upon examination, shall have the capacity, skill, experience and habits of sobriety requisite to perform the duties of an engineer, and no person possessing such qualifications shall be refused a license. Each applicant for a license shall at the time of filing his application pay to the Inspector of Boilers and Elevators a fee of two dollars for each examination, and all money so received by the Inspector

of Boilers and Elevators shall be paid into the City Treasury, as provided by section 2209, but no charge shall be made for renewals. All certificates of licenses granted shall be signed by not less than two, and may be signed by all the members of the Board. The Board of Engineers may adopt such rules and regulations as they deem proper, not inconsistent with this Chapter and general law. A full Board of Engineers, by an unanimous vote, shall have the power to revoke an engineer's license for inebriety, dishonesty or neglect of his duties, when in charge of an engine or boiler in use, and may order the reinspection of any boiler whenever they shall deem it necessary for the public safety; but no license shall be permanently revoked for cause without first giving the accused party an opportunity to be heard in his own defense. In Fig. 296 is shown the St. Louis form of a stationary engineer's license, as issued by the Board of Examining Engineers for that city.

Inspections.—All inspections made in the city, whether by deputy or assistant inspectors, are made subject to the approval of the Inspector of Boilers and Elevators.

Number.—In the City of St. Louis there are 2008 boilers in use, operated by 1398 engineers. There are 2540 elevators in operation, divided as follows, viz.:

Hand Elevators, 461.

Power Freight Elevators, 1525.

Power Passenger Elevators, 554.

Requiring a total of 9332 inspections annually.

Plan for a Power Plant.—In Fig. 297 is shown a plan for a power plant of the most common size, consisting of a Corliss engine, two boilers in battery, with smoke connection to outside stack on a brick base, feed water heater, pump and piping for same.



St. Louis Stationary Engineer's License.

Fig. 296.

CIRCUMFERENCE OF CIRCLES

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
1	3.1416	26	81.681	51	160.22	76	238.76	101	317.30	126	395.84	151	474.24
2	6.2832	27	84.823	52	163.36	77	241.90	102	320.44	127	398.96	152	477.38
3	9.4248	28	87.965	53	166.50	78	245.04	103	323.58	128	402.12	153	480.50
4	12.5664	29	91.106	54	169.65	79	248.19	104	326.73	129	405.27	154	483.62
5	15.7080	30	94.248	55	172.79	80	251.33	105	329.87	130	408.41	155	486.74
6	18.8500	31	97.389	56	175.93	81	254.47	106	333.01	131	411.55	156	489.86
7	21.9913	32	100.53	57	179.07	82	257.61	107	336.15	132	414.69	157	492.98
8	25.1333	33	103.67	58	182.21	83	260.75	108	339.29	133	417.83	158	496.10
9	28.2744	34	106.81	59	185.35	84	263.89	109	342.43	134	420.97	159	499.22
10	31.416	35	109.96	60	188.50	85	267.04	110	345.58	135	424.12	160	502.34
11	34.558	36	113.10	61	191.64	86	270.18	111	348.72	136	427.26	161	505.46
12	37.699	37	116.24	62	194.78	87	273.32	112	351.86	137	430.40	162	508.58
13	40.841	38	119.38	63	197.92	88	276.46	113	355.00	138	433.54	163	511.70
14	43.982	39	122.52	64	201.06	89	279.60	114	358.14	139	436.68	164	514.82
15	47.124	40	125.66	65	204.20	90	282.74	115	361.28	140	439.82	165	517.94
16	50.265	41	128.81	66	207.35	91	285.88	116	364.42	141	442.96	166	521.06
17	53.407	42	131.95	67	210.49	92	289.03	117	367.57	142	446.11	167	524.18
18	56.549	43	135.09	68	213.63	93	292.17	118	370.71	143	449.25	168	527.30
19	59.690	44	138.23	69	216.77	94	295.31	119	373.85	144	452.39	169	530.42
20	62.832	45	141.37	70	219.91	95	298.45	120	376.99	145	455.53	170	533.54
21	65.973	46	144.51	71	223.05	96	301.59	121	380.13	146	458.67	171	536.66
22	69.115	47	147.65	72	226.19	97	304.73	122	383.27	147	461.81	172	539.78
23	72.257	48	150.80	73	229.34	98	307.88	123	386.42	148	464.95	173	542.90
24	75.398	49	153.94	74	232.48	99	311.02	124	389.56	149	468.10	174	546.02
25	78.540	50	157.08	75	235.63	100	314.16	125	392.70	150	471.24	175	549.14

Table No. 28.

Table of Areas of Circles

Diameter	Area	Diameter	Area	Diameter	Area	Diameter	Area
1/8 in.	.012	7 1/8 in.	47.17	18 1/8 in.	268.80	37 1/8 in.	1104.5
1/4 "	.049	8 "	50.26	19 "	283.52	38 "	1134.1
3/8 "	.110	8 1/4 "	53.45	19 1/2 "	298.64	38 1/2 "	1164.2
1/2 "	.196	8 1/2 "	56.74	20 "	314.16	39 "	1194.6
5/8 "	.307	8 3/4 "	60.13	20 1/2 "	330.06	39 1/2 "	1225.4
3/4 "	.442	9 "	63.61	21 "	346.36	40 "	1256.6
7/8 "	.601	9 1/4 "	67.20	21 1/2 "	363.05	40 1/2 "	1288.3
1 "	.785	9 1/2 "	70.88	22 "	380.13	41 "	1320.3
1 1/8 "	.994	9 3/4 "	74.66	22 1/2 "	397.60	41 1/2 "	1352.7
1 1/4 "	1.227	10 "	78.54	23 "	415.47	42 "	1385.4
1 1/2 "	1.484	10 1/4 "	82.51	23 1/2 "	433.73	42 1/2 "	1418.0
1 3/4 "	1.767	10 1/2 "	86.59	24 "	452.39	43 "	1452.2
2 "	2.073	10 3/4 "	90.76	24 1/2 "	471.43	43 1/2 "	1486.2
2 1/8 "	2.405	11 "	95.03	25 "	490.87	44 "	1520.5
2 1/4 "	2.761	11 1/4 "	99.40	25 1/2 "	510.70	44 1/2 "	1555.3
2 1/2 "	3.14	11 1/2 "	103.86	26 "	530.93	45 "	1590.4
2 3/4 "	3.97	11 3/4 "	108.43	26 1/2 "	551.54	45 1/2 "	1626.0
3 "	4.90	12 "	113.09	27 "	572.55	46 "	1661.9
3 1/8 "	5.93	12 1/4 "	117.85	27 1/2 "	593.95	46 1/2 "	1698.2
3 1/4 "	7.06	12 1/2 "	122.71	28 "	615.75	47 "	1734.9
3 1/2 "	8.29	12 3/4 "	127.67	28 1/2 "	637.94	47 1/2 "	1772.1
3 3/4 "	9.63	13 "	132.73	29 "	660.52	48 "	1809.6
4 "	11.04	13 1/4 "	137.88	29 1/2 "	683.49	48 1/2 "	1847.5
4 1/8 "	12.53	13 1/2 "	143.13	30 "	706.86	49 "	1885.7
4 1/4 "	14.18	13 3/4 "	148.48	30 1/2 "	730.61	49 1/2 "	1924.4
4 1/2 "	15.90	14 "	153.93	31 "	754.76	50 "	1963.5
4 3/4 "	17.72	14 1/4 "	159.48	31 1/2 "	779.81	50 1/2 "	2003.0
5 "	19.63	14 1/2 "	165.13	32 "	804.25	51 "	2042.8
5 1/8 "	21.64	14 3/4 "	170.87	32 1/2 "	829.57	51 1/2 "	2083.1
5 1/4 "	23.75	15 "	176.71	33 "	855.30	52 "	2123.7
5 1/2 "	25.96	15 1/4 "	182.65	33 1/2 "	881.41	52 1/2 "	2164.8
6 "	28.27	15 1/2 "	188.69	34 "	907.92	53 "	2206.2
6 1/8 "	30.67	15 3/4 "	194.82	34 1/2 "	934.82	53 1/2 "	2248.0
6 1/4 "	33.18	16 "	201.06	35 "	962.11	54 "	2290.2
6 1/2 "	35.78	16 1/4 "	213.82	35 1/2 "	989.80	54 1/2 "	2332.8
6 3/4 "	38.48	16 1/2 "	226.98	36 "	1017.88	55 "	2375.8
7 "	41.28	17 "	240.52	36 1/2 "	1046.4	55 1/2 "	2419.2
7 1/8 "	44.17	18 "	254.46	37 "	1075.2	56 "	2463.0

Table No. 29.

WEIGHTS.

Metric Denominations and Equivalents in Denominations in Use.

Name.	No. Grams.	Weight of what quantity of water at max. density.
Mulier or tonneau	= 1,000,000	= 1 cubic meter.
Quintal	= 100,000	= 1 hectoliter.
Myriagram	= 10,000	= 10 liters.
Kilogram or Kilo	= 1,000	= 1 liter.
Hectogram	= 100	= 1 deciliter
Dekagram	= 10	= 10 cubic centimeters.
Gram	= 1	= 1 cubic centimeter.
Decigram	= .1	= .1 cubic centimeter.
Centigram	= .01	= .01 cubic centimeters.
Milligram	= .001	= 1 cubic millimeter.

MEASURES OF LENGTH.

Myriameter	= 10,000 meters	= 6.2137 miles.
Kilometer	= 1,000 meters	= 0.62137 m. or 3,280 ft. 10 in.
Hectometer	= 100 meters	= 328 ft. and 1 inch.
Dekameter	= 10 meters	= 39.37 inches.

MEASURES OF SURFACE.

Hectare	= 10,000 square meters	= 2.471 acres.
Are	= 100 square meters	= 119.6 square yards.

MEASURES OF CAPACITY.

Name.	No. Liters.	Cubic Measure.	Dry Measure.
Kiloliter	= 1,000	= 1 cubic meter.	= 1.358 cubic yards.
Hectoliter	= 100	= .1 cubic meter	= 3.53 pts.
Decaliter	= 10	= 10 cu. decimeters	= 8.96 quarts.
Liter	= 1	= 1 cu. decimeter	= 0.998 quart.
Deciliter	= .1	= .1 cu. decimeter	= 6.102 cu. inches.
Centiliter	= .01	= 10 cu. centimeters	= 0.6102 cu. inch.
Milliliter	= .001	= 1 cu. centimeter	= 0.061 cu. inch.

Name.	No. Grams.	Avoirdupois Weight.
Mulier or tonneau	= 1,000,000	= 2,204.6 pounds.
Quintal	= 100,000	= 220.46 pounds.
Myriagram	= 10,000	= 22.046 pounds.
Kilogram or Kilo	= 1,000	= 2.2046 pounds.
Hectogram	= 100	= 3.5274 ounces.
Dekagram	= 10	= 0.3527 ounce.
Gram	= 1	= 15.432 grains.
Decigram	= .1	= 1.5432 grains.
Centigram	= .01	= 0.1543 grain.
Milligram	= .001	= 0.0154 grain.

Meter	= 1 meter	= 39.37 inches.
Decimeter	= .1 of a meter	= 3.937 inches.
Centimeter	= .01 of a meter	= 0.3937 inch.
Millimeter	= .001 of a meter	= 0.0394 inch.

Centare = 1 square meter = 1.550 square inches

Name.	No. Liters.	Cubic Measure.	Wine Measure.
Kiloliter	= 1,000	= 1 cubic meter	= 264.17 gallons.
Hectoliter	= 100	= .1 cubic meter	= 26.417 gallons.
Decaliter	= 10	= 10 cu. decimeters	= 2.6417 gallons.
Liter	= 1	= 1 cu. decimeter	= 1.0567 quarts.
Deciliter	= .1	= .1 cu. decimeter	= 0.845 gill.
Centiliter	= .01	= 10 cu. centimeters	= 0.338 fluid oz.
Milliliter	= .001	= 1 cu. centimeter	= 0.27 fluid oz.

The Metric System.

Table No. 30.

TABLE OF DECIMAL EQUIVALENTS

Of 8ths, 16ths, 32ds and 64ths of an Inch.

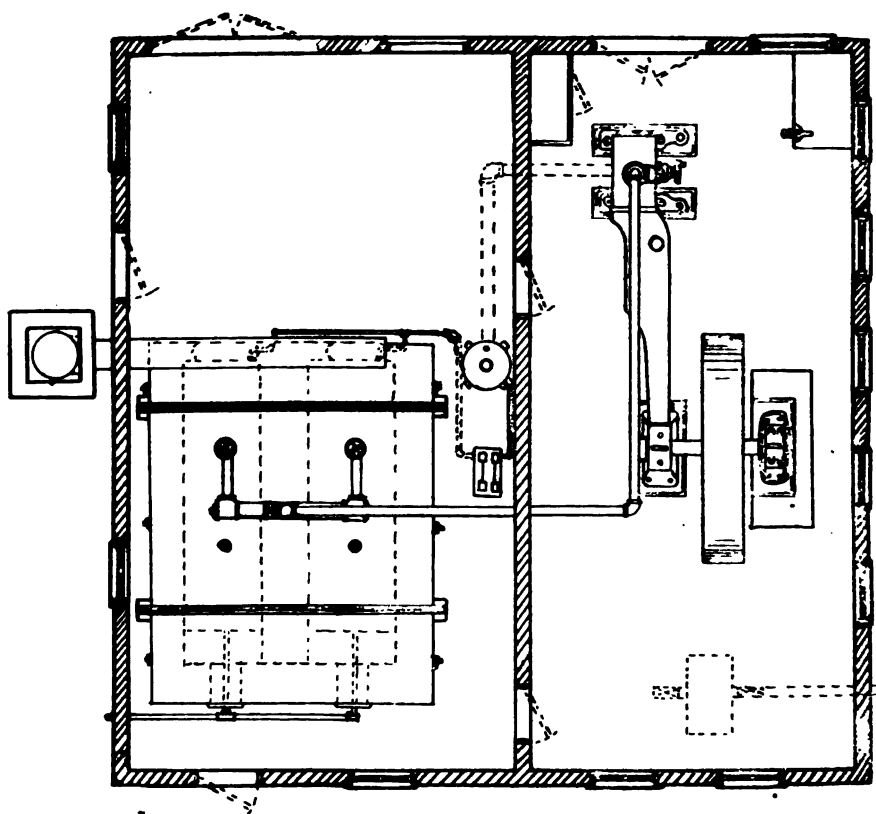
8ths.	$\frac{1}{8} = .125$	$\frac{1}{8} = .28125$	$\frac{1}{8} = .296875$
$\frac{1}{4} = .250$	$\frac{1}{4} = .375$	$\frac{1}{4} = .40625$	$\frac{1}{4} = .421875$
$\frac{3}{8} = .375$	$\frac{3}{8} = .500$	$\frac{3}{8} = .53125$	$\frac{3}{8} = .546875$
$\frac{1}{2} = .500$	$\frac{1}{2} = .625$	$\frac{1}{2} = .65625$	$\frac{1}{2} = .671875$
$\frac{5}{8} = .625$	$\frac{5}{8} = .750$	$\frac{5}{8} = .78125$	$\frac{5}{8} = .796875$
$\frac{3}{4} = .750$	$\frac{3}{4} = .875$	$\frac{3}{4} = .90625$	$\frac{3}{4} = .921875$
$\frac{7}{8} = .875$	16ths.	$\frac{7}{8} = .9375$	$\frac{7}{8} = .953125$
$\frac{1}{16} = .0625$	$\frac{1}{16} = .1875$	$\frac{1}{16} = .203125$	$\frac{1}{16} = .21875$
$\frac{1}{8} = .125$	$\frac{1}{8} = .3125$	$\frac{1}{8} = .328125$	$\frac{1}{8} = .34375$
$\frac{3}{16} = .1875$	$\frac{3}{16} = .4375$	$\frac{3}{16} = .453125$	$\frac{3}{16} = .46875$
$\frac{1}{4} = .250$	$\frac{1}{4} = .5625$	$\frac{1}{4} = .578125$	$\frac{1}{4} = .59375$
$\frac{5}{16} = .3125$	$\frac{5}{16} = .6875$	$\frac{5}{16} = .703125$	$\frac{5}{16} = .71875$
$\frac{3}{8} = .375$	$\frac{3}{8} = .8125$	$\frac{3}{8} = .828125$	$\frac{3}{8} = .84375$
$\frac{7}{16} = .4375$	$\frac{7}{16} = .9375$	$\frac{7}{16} = .953125$	$\frac{7}{16} = .96875$
$\frac{1}{2} = .500$	32ds.	$\frac{1}{2} = .984375$	
$\frac{1}{32} = .03125$	$\frac{1}{32} = .09375$		
$\frac{1}{16} = .0625$	$\frac{1}{16} = .15625$		
$\frac{3}{32} = .09375$	$\frac{3}{32} = .21875$		
$\frac{1}{8} = .125$			
$\frac{5}{32} = .15625$			
$\frac{3}{16} = .1875$			
$\frac{7}{32} = .21875$			
$\frac{1}{4} = .250$			
$\frac{9}{32} = .28125$			
$\frac{5}{16} = .3125$			
$\frac{11}{32} = .34375$			
$\frac{3}{8} = .375$			
$\frac{13}{32} = .40625$			
$\frac{7}{16} = .4375$			
$\frac{15}{32} = .46875$			
$\frac{1}{2} = .500$			
$\frac{17}{32} = .53125$			
$\frac{9}{16} = .5625$			
$\frac{19}{32} = .59375$			
$\frac{5}{8} = .625$			
$\frac{21}{32} = .65625$			
$\frac{11}{16} = .6875$			
$\frac{23}{32} = .71875$			
$\frac{3}{4} = .750$			
$\frac{25}{32} = .78125$			
$\frac{13}{16} = .8125$			
$\frac{27}{32} = .84375$			
$\frac{7}{8} = .875$			
$\frac{29}{32} = .90625$			
$\frac{15}{16} = .9375$			
$\frac{31}{32} = .96875$			
$1 = 1.00000$			

CAPACITY OF TANKS IN U. S. GALLONS.

DIAMETERS.

	5 ft.	5½ ft.	6 ft.	6½ ft.	7 ft.	7½ ft.	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	11 ft.
5 ft.	734	888	1057	1241	1439	1652	1880	2122	2379	2768	2987	3554
5 ft. 6 in.	808	977	1163	1365	1583	1817	2068	2334	2617	3045	3281	3910
6 ft.	881	1066	1269	1489	1727	1983	2256	2546	2855	3322	3525	4265
6 ft. 6 in.	955	1155	1374	1613	1871	2148	2444	2759	3093	3599	3819	4621
7 ft.	1028	1244	1480	1737	2015	2318	2632	2971	3331	3875	4112	4976
7 ft. 6 in.	1100	1332	1586	1861	2159	2478	2820	3183	3569	4152	4406	5392
8 ft.	1175	1421	1692	1986	2303	2643	3007	3395	3807	4429	4700	5687
8 ft. 6 in.	1248	1510	1797	2110	2446	2809	3196	3607	4045	4706	4998	6042
9 ft.	1322	1599	1903	2234	2590	2974	3384	3820	4283	4988	5287	6398
9 ft. 6 in.	1395	1688	2008	2358	2734	3139	3572	4032	4521	5259	5581	6753
10 ft.	1468	1776	2114	2482	2878	3304	3760	4244	4758	5536	5874	7108

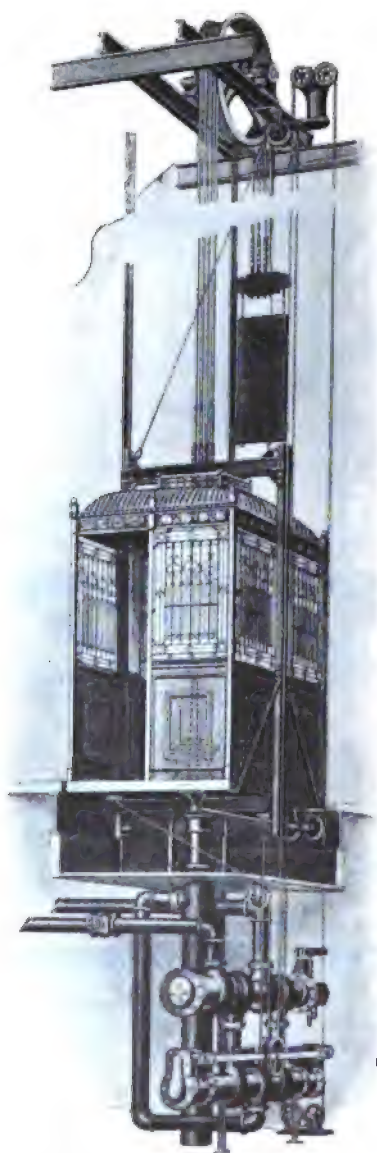
Table No. 23.



Plan of Power Plant.

Fig. 297.

APPENDIX



The Standard Plunger Elevator.

Fig. 300.

THE STANDARD PLUNGER ELEVATOR OF NEW YORK.

Description.—In the Plunger Elevator the car is supported from beneath by a moving column or plunger of approximately the same length as the travel of the elevator. This plunger works in a cylinder sunk vertically in the ground directly under the car. The cylinder is closed at the bottom, and at the top provided with a stuffing box through which the plunger passes; also with an opening for the inlet and outlet of water. The space between the plunger and cylinder is filled with water which sustains and moves the plunger and with it the car up or down. The opening in the cylinder is connected through a pipe to a three-way valve so arranged that when in central position the opening in the cylinder is closed and the elevator at rest. When the valve is opened in one direction, water under pressure will enter the cylinder and force the plunger upward. If the valve is reversed the water in the cylinder is forced out by the weight of the car plunger, and the elevator will come down. This valve may be operated directly **by hand** through a rope running through the car, or controlled **hydraulically** by means of a pilot valve, which in turn is operated directly by the operator. The weight of the car plunger is usually counterbalanced, leaving only enough preponderance on the car side to make the elevator come **down** at the desired speed.

Construction.—The car frame is T steel, strongly bolted and braced, and provided with easy running shoes. The plunger is made of specially selected steel pipe finished to a uniform outside diameter and highly polished. The separate sections are joined together by extra heavy inside steel nipples. The cylinder is made of steel pipe joined together by outside coupling, making butt

joints. The bottom is welded together, and the top is provided with an extra heavy casting with opening for the water, and means for attaching the stuffing box. The well for the cylinder is bored by special machinery, and where necessary provided with a steel casing. The car and counterweight run on steel guides, and the connection between same are made of extra heavy iron or steel ropes of proper weight to compensate for the variable buoyancy of the plunger.

Merits.—The plunger elevator is absolutely safe from falling as the car is supported from beneath, and cannot go down faster than the water escapes from the cylinder. There is nothing to wear out except the packings, which can easily be renewed. The power is exerted **direct**, without intervention of **sheaves** or **cables** which insures the highest possible efficiency, and an absolute freedom from vibration. As the entire machinery is generally located in the basement under the elevator, no valuable floor space is occupied in the building. The simplicity of the machine, which has nothing to wear except the packings, makes it of very long life and great reliability. Its merits are summed up in its **safety**, **economy** of operation and **repairs**, smooth, quiet running, long life and **durability**.

SPECIFICATIONS FOR STANDARD PLUNGER ELEVATOR.

The Standard Plunger Elevator Company hereby proposes to furnish and install—of the direct-acting plunger hydraulic type, together with pumping plant for same, as per the following specifications:

The service, runs, loads and speeds, sizes of plungers and cylinders, to be as per schedule below:

CYLINDER WELLS.

The cylinder wells will be of suitable size and shall be sunk by us into the ground under the hatchways to

proper depths by our improved rotary drilling or wet driving process, and the excavated material removed from the premises by us.

We shall furnish these wells with mild steel casing, set in place for their entire depths or until solid rock is encountered.

The water necessary for the drilling will be furnished by the owners at the regular street pressure, and they are also to furnish proper connections on the supply and sewer pipes for obtaining and disposing of this water by us.

CYLINDERS.

The cylinders of suitable length will be constructed of selected steel tubing having a large factor of safety, and will be protected from rust by a coating of asphalt or other preservative preparation.

All cylinder lengths are to be accurately straightened, squared, threaded and coupled so as to secure accurate alignment, and the cylinders are to be thoroughly tested by hydrostatic pressure before leaving the factory.

The cylinders will be closed at the bottom, and shall have stuffing boxes at the top accurately fitting the plungers, and provided with our improved plunger packing.

PLUNGERS.

The plungers will be of selected steel tubing, carefully straightened, turned and polished, of proper lengths, being so proportioned as to secure maximum lightness consistent with suitable strength. They shall be firmly secured to the platforms by platens, and the lower lengths of the plungers shall also be independently secured by our patent attachment to the platforms by inside bolts or cables. The sections are to be joined by our improved internal couplings, and each plunger is to be uniform in diameter and true in alignment. They are to be thoroughly gauged inside and out.

CONTROLLING VALVES.

The controlling valves for the passenger elevators and combination freight and passenger elevator will be our three-way balanced pattern, with brass linings and pistons, having independently graduated openings for stopping and starting so as to avoid shock or jar, and to secure maximum smoothness in the control of the cars.

The controlling valve for the freight elevator will be our three-way balanced pattern, with rack and pinion or lever control.

LEVER AND CONNECTIONS.

THE CONTROLLING AND AUTOMATIC STOP APPARATUS.

Each passenger elevator car and the combination freight and passenger elevator car will be provided with a controlling lever having center stop notch, which shall be connected by our double controlling valves.

OVERHEAD BEAMS FOR COUNTER WEIGHTS.

The overhead supporting beams will be of steel of suitable section, furnished, erected and firmly secured in position by us upon proper supports provided by the owners in the construction of the hatchways.

PILOT VALVES.

The controlling valves for the elevator shall be governed in their motion, both in direction and extent, by pilot valves, thus securing a positive control from the lever in the car at all speeds.

AUTOMATIC LIMITATION STOP VALVES.

Each elevator will be provided with our automatic limitation stop valves, operating independently of all other mechanism, which brings the car to a gradual stop at the upper and lower terminals of travel, whether controlled by the operator or not.

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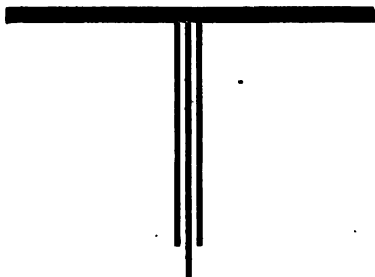
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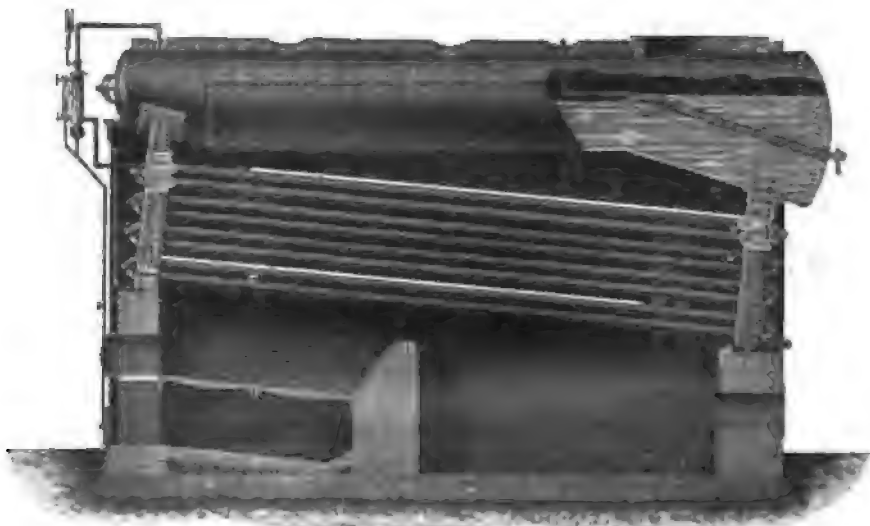
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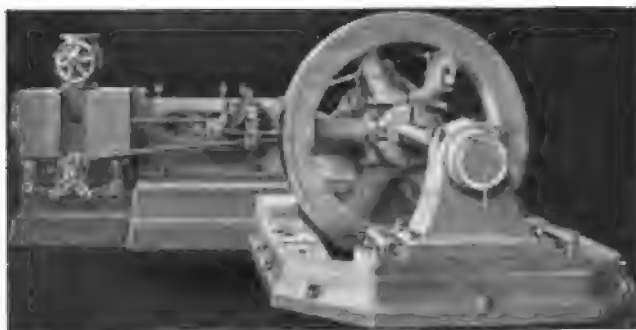
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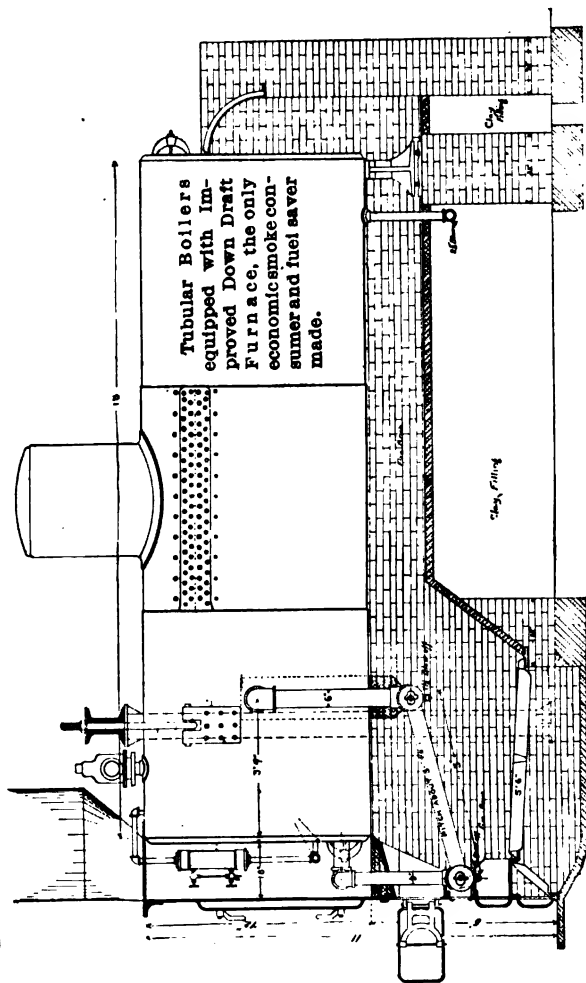
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